Development of

RF ATTENUATORS

Technical Report
to
U.S. Naval Weapons Laboratory
Dahlgren, Virginia

Contract N178-8056
Nov. 1, 1962 to June 30, 1963
(Completion of Phase II)

Scintilla Division
SIDNEY, NEW YORK
Bendix

Technical Report

November 1, 1962 through June 30, 1963

on

Radio Interference Guard (RIG)

Low-Pass Radio Frequency Attenuator

for the

U. S. Naval Weapons Laboratory

Dahlgren, Virginia

Contract No. N178-8056
(Completion of Phase II)

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Preface

The U.S. Navy's Hazards of Electromagnetic Radiation to Ordnance (HERO) Program is concerned with providing adequate protection of weapon electro-explosive devices (EED'S) against spurious energies induced in their associated circuits by electromagnetic fields. The source of this spurious energy is generally shipboard radar and communications equipment. The use of this equipment must now be restricted during certain operations with ordnance, or the ordnance operations must be accomplished at a point remote from the transmitting antennas.

As a result of studies made under the HERO Program, a miniature low-pass attenuator of novel design and capabilities has been conceived. This device employs the intrinsic low-pass characteristics of a metal barrier in a filter and/or attenuator application as a means of protecting EED'S from spurious radio frequency energies.

Feasibility of this device, known as the Radio Interference Guard (RIG) RF Attenuator, has been demonstrated and a patent application was filed at the U.S. Patent Office on 29 December 1961 under Navy Case No. 33460 Patent Serial No. 163162 by Wing Commander R. I. Gray.

Table of Contents

List of Illustrations

Technical Report
Phase II

Contract No. N178-8065

1.0 Summary

1.1 This report covers the work accomplished by the Scintilla Division of The Bendix Corporation during the period of November 1, 1962 to June 30, 1963 of Contract N 178-8056 for the Naval Weapons Laboratory, Dahlgren, Virginia. Contract N 178-8056 is concerned with the development of a miniature low pass radio interference attenuator device herein referred to as RIG (Radio Interference Guard). The objective is to develop and determine the most suitable design, materials, and construction techniques to obtain optimum efficiency and reliability of the RIG device as well as to fabricate prototype models and conduct necessary RF attenuation and environmental tests in accordance with Scintilla Division Proposal 619, Development of RF Attenuators for Project HERO, and contract N 178-8056.

1.2 The work accomplished under the contract during the period from June 1 to October 31, 1962, as described in the previously issued Phase I report, was concerned with the basic theory of operation of the RIG and with the development and testing of six RIG designs. Further work with these designs is reported herein.

1.3 Based on the results obtained during Phase I, a special design for a two unit RIG device was agreed upon by NWL and Scintilla Division personnel in November 1962. The work of developing and determining the most suitable two unit design, materials, and construction techniques for optimum efficiency and reliability was added to the Phase II task and is also reported herein. This work is based on the information, including analytical approaches and preliminary test data, which was previously gained in working with the single unit RIG device.

2.0 General Requirements

2.1 The following general requirements were established as design objectives:

2.1.1 Squib to be used: The Mark I squib will be used to terminate the RIG device at the present time.

2.1.2 RIG Requirements:

a. Attenuation

1. DC attenuation is to be 6 db.

2. Attenuation is to be 40 db at 100 KC.

b. Output Current

Output current to be 1.5 amps minimum.

c. Firing Voltage

28 volts DC, 28 volts 60 cycle, or 28 volts 400 cycle.

d. Response Time

To be a maximum of 10 milliseconds from application of firing pulse to initiation.

e. Breakdown Voltage

To be 100 volts peak on coaxial tube and 1,000 volts peak for other components.

f. Power Dissipation

The device at an ambient temperature of 50°C shall dissipate 10 watts of power at DC and 10 MC for a period of one hour.

g. General Environment

Must withstand requirements of MIL-D-21625 and MIL-E-5272C, and must withstand 100 watts for 10 milliseconds in the pass band.

3.0 Theory

3.1 Theory of Operation - Single Unit RIG

3.1.1 The theory of operation of the one unit RIG device is described in detail in the Phase I Report on this contract.

The circuitry for the single unit is shown in figure 1.

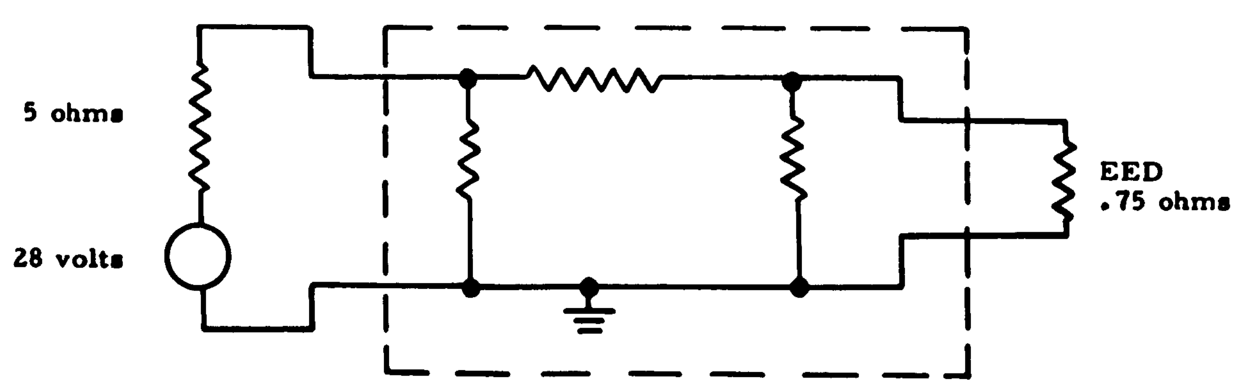


Figure I

3.2 Theory of Operation - Double Unit RIG

3.2.1 The two unit RIG device is to be used as an RF attenuator in a balanced two wire circuit. Its purpose and idealized concept is the same as the single unit device which is described in the Phase I report. Briefly stated, its purpose is to reduce to a negligible level the radio frequency power transmitted in the attenuation band without appreciably attenuating DC and low frequency AC in the pass band as explained by Wing Commander R. I. Gray in "A Note on the Use of Attenuators in Balanced and Unbalanced Networks" (see appendix).

a. The circuitry for the double unit is shown in figure 2.

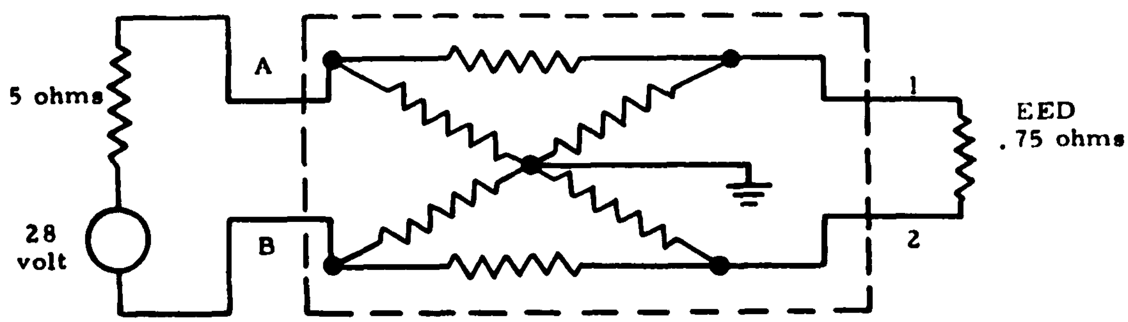


Figure 2

b. The double unit RIG was tested as a single unit device (see figure 3) because there are no two pin above ground RF generators.

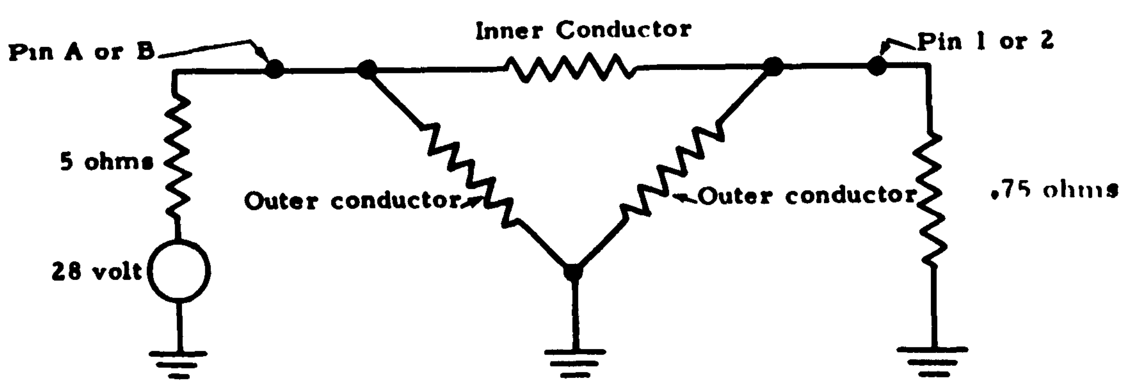


Figure 3

NOTE: When connected to input Pin A, use output Pin 1, when connected to input Pin B, use output Pin 2.

4.0 Detailed Report

4.1 General Description

Five coaxial cable types were wound into RIG devices as shown in design drawing L-19910-49 (figure 15), a sixth and seventh type were wound according to design drawing L-19910-66, (figure 16), and an eighth type was wound according to design drawing L-19910-70 (figure 17). The physical dimensions, material, design objectives, and typical electrical values are given in Table I (see appendix). It should be noted that drawings L-19910-49 and -66 show single unit RIG's while drawing L-19910-70 shows a double unit design having two windings which are concentric with each other. The input connector of the latter design is a glass seal Bendix PC1H two pin connector. The output connector is a Cannon Twinax TM-RB-M-O.

4.2 Manufacturing Comments

4.2.1 Insulation of Coaxial Cable

All of the RIG devices were wound using coaxial cable which was coated with Dupont ML high temperature polyimide lacquer in the Materials Laboratory. Samples of the cable were baked for two hours holding a core temperature of 480°F. The insulation of the five samples tested withstood a minimum of 1500 volts DC.

4.2.2 Winding and Soldering the Coaxial Cable

4.2.2.1 The wall thickness of the .0015 in. tubing gave considerable trouble in forming around the spool. Due to the thin wall thickness, slight cracks appeared after winding. If any cracks were detected, as evidenced by increase in electrical resistance as well as by a visual detection, these assemblies were rejected. In the case of the 99% iron, it was necessary to reject all of the first lot of .0015 inch wall thickness purchased and ·order the cable from Uniform Tube Co.

4.2.2.2. When the two ends of the cente. conductor of the coaxial cable were soldered to the outside shield, a certain amount of care had to be used to prevent the outside shield from breaking, yet obtain a good tight solder joint. To generalize, it was necessary to use care in handling the coaxial cable, and especially the .0015 inch wall type, in all operations.

4.2.3 Resistance Checks

The resistance of the coaxial cable was checked after each significant operation to ensure proper assembly.

4.3 Analysis of DC Attenuation - Two Unit Design

4.3.1 The DC attenuation is dependent on the resistance R_1 of the outer conductor and the resistance R_2 of the inner conductor. If K and C are the resistances per unit length (ohms/ft) of the outer and inner conductor, respectively, and n is the length (ft) of the cable, then R_1 and R_2 are defined as specified in figure 4.

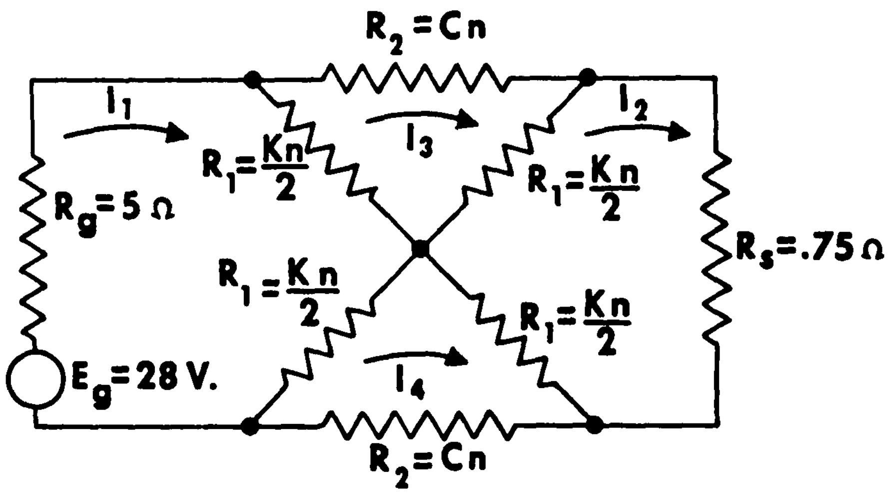


Figure 4

4.3.2 **Using loop analysis, the following expressions may be derived for the loop currents:**

$$E_g = R_g I_1 + R_1 (I_1 - I_3) + R_1 (I_1 - I_4)$$

(a) $$R_1 (I_1 - I_3) = R_2 I_3 + R_1 (I_3 - I_2)$$

$$R_1 (I_1 - I_4) = R_2 I_4 + R_1 (I_4 - I_2)$$

$$R_s I_2 = R_1 (I_3 - I_2) + R_1 (I_4 - I_2)$$

4.3.3 **Since the middle two expressions are identical, it may be concluded that $I_3 = I_4$. This permits the expressions to be written as follows:**

$$E_g = R_g I_1 + 2R_1 (I_1 - I_3)$$

(b) $$R_1 (I_1 - I_3) = R_2 I_3 + R_1 (I_3 - I_2)$$

$$R_s I_2 = 2R_1 (I_3 - I_2)$$

4.3.4 The above expressions also happen to be the analysis of the network in figure 5.

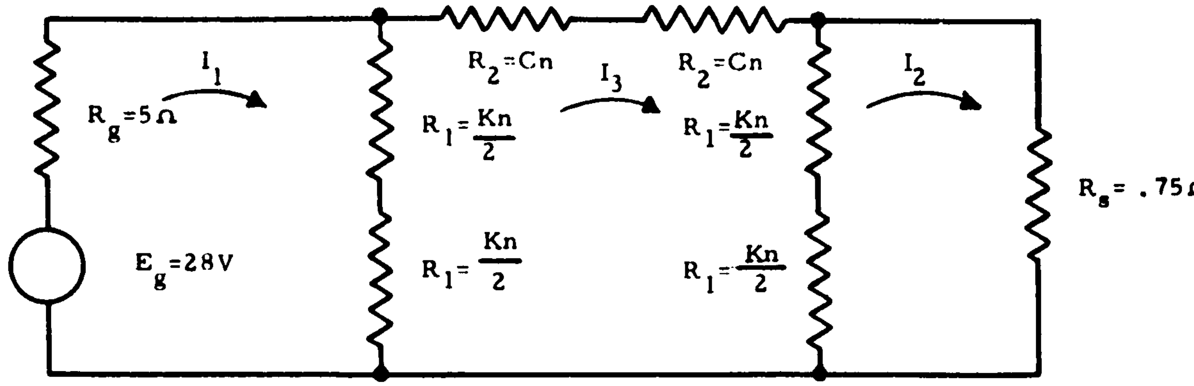


Figure 5

Therefore it may be concluded that the two circuits (figures 4 and 5) are identical for analytical purposes.

4.3.5 The expressions for these circuits may be written in the following matrix form:

$$(c)\quad \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} (R_g + 2R_1) & (O) & -(2R_1) \\ (O) & (R_s + 2R_1) & (-2R_1) \\ (-R_1) & (-R_1) & (2R_1 + R_2) \end{bmatrix}^{-1} \times \begin{bmatrix} E_g \\ O \\ O \end{bmatrix}$$

4.3.6 This shows that all expressions for current are independent of each other and each contains the variables n, K and C. The solution of equation (c) gives the following expressions for I_1 and I_2:

$$(d)\quad I_1 = \frac{\left(R_1 + R_s + \dfrac{R_2 R_s}{2R_1} + R_2\right) E_g}{R_g R_s + \dfrac{R_2 R_g R_s}{2R_1} + R_1 R_s + R_2 R_s + R_1 R_g + R_2 R_g + 2R_1 R_2}$$

(e) $$I_2 = \frac{R_1 E_g}{R_g R_s + \frac{R_2 R_g R_s}{2R_1} + R_1 R_s + R_2 R_s + R_1 R_g + R_2 R_g + 2R_1 R_2}$$

4.3.7 Expressions (d) and (e) may be written in terms of K, C and n by substituting the following relationships into them:

(f) $$R_1 = \frac{Kn}{2}$$

(g) $$R_2 = Cn$$

4.3.8 After these substitutions have been made, equations (d) and (e) can be rearranged to give the following expressions:

(h) $$\left[\frac{K}{C}\right] = \frac{-(2S[nC] + 2T) - \sqrt{(2S[nC] + 2T)^2 - 8[nC](2[nC] + R)T}}{2[nC](2[nC] + R)}$$

(i) $$\left[\frac{K}{C}\right] = \frac{-(2R'[nC] + 2T') + \sqrt{(2R'[nC] + 2T')^2 - 8[nC](2[nC] + R')T'}}{2[nC](2[nC] + R')}$$

4.3.9 Where in the interests of brevity:

(j) $$R = R_s + R_g - \frac{E_g}{I_2}$$

(k) $$S = R_g + R_s$$

(l) $$T = R_g R_s$$

(m) $$R' = R_s + R_g - \frac{E_g}{I_1}$$

(n) $$T' = \left(R_g - \frac{E_g}{I_1}\right) R_s$$

4.3.10 Expressions (h) and (i) make it possible to plot the grouped parameters $\frac{K}{C}$ and $[nC]$ on a single set of coordinate axes by assigning specific values to R_s (.75 OHMS), E_g (28 VOLTS) and R_g (5 OHMS).

The result is two families of curves. The first family comes from expression (h) by assigning specific values of I_2. The second comes from expression (i) by assigning specific values of I_1. The intersections of these two families gives specific solutions for the circuit.

4.3.11 The two families were plotted for a broad range of values of I_1 and I_2 by using data obtained from computer runs. The computer has been programmed so that additional runs may be made when new values for R_s, R_g and E_g are specified. The plot for the R_s, R_g and E_g previously specified is shown in figure 13. It should be noted that DC power attenuation can be calculated by taking the I_1 and I_2 at the intersection of specific curves and substituting them into the following expressions:

$$\text{(o)} \quad \begin{matrix}\text{POWER}\\ \text{ATTENUATION}\\ \text{(db)}\end{matrix} = 10 \log\left(\frac{R_{input}\, I_1^2}{R_s I_2^2}\right)$$

Where:

$$\text{(p)} \quad R_{input} = \frac{2R_1\,(4R_2R_1 + 2R_2R_s + 2R_1R_s)}{(4R_2R_1 + 2R_2R_s + 4R_1R_s + 4R_1^2)}$$

as derived from the circuit. Combining these two expressions results in:

$$\text{(q)} \quad \begin{matrix}\text{POWER}\\ \text{ATTENUATION}\\ \text{(db)}\end{matrix} = 10 \log\left[\left(\frac{2R_1}{R_s}\right)\left(\frac{4R_2R_1 + 2R_2R_s + 2R_1R_s}{4R_2R_1 + 2R_2R_s + 4R_1R_s + 4R_1^2}\right)\left(\frac{I_1}{I_2}\right)^2\right]$$

4.3.12 Of course, expressions (d) and (e) may be substituted into expression (q) giving:

$$\text{(r)} \quad \begin{matrix}\text{POWER}\\ \text{ATTENUATION}\\ \text{(db)}\end{matrix} = 10 \log\left[\frac{((2R_1+R_2)\,(2R_1+R_s) - 2R_1^2)\,(R_1^2R_s + 2R_1^2R_2 + R_1R_2R_s)}{2R_1^4\, R_s}\right]$$

These results may be compared to those of the single unit circuit shown in figure 6.

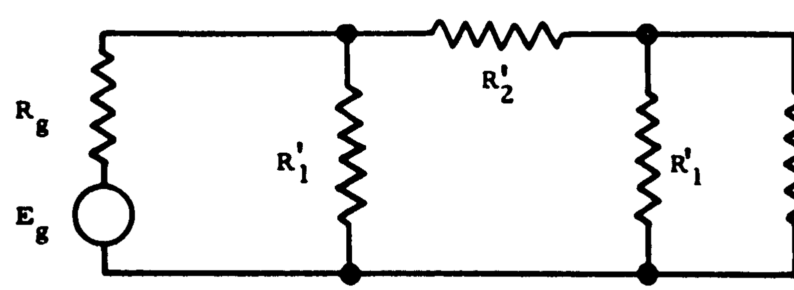


Figure 6

4.3.13 The expression for the DC power attenuation in the circuit of figure 6 was previously derived in the Phase I report and is:

$$\text{(s)}\quad \begin{array}{l}\text{POWER}\\ \text{ATTENUATION}\\ \text{(db)}\end{array} = 10 \log \left[\frac{((2R'_1 + R'_2)(R'_1 + R'_s) - R'^2_1)(R'^2_1 R'_s + R'^2_1 R'_2 + R'_1 R'_2 R'_s)}{R'^4_1 R'_s} \right]$$

4.3.14 Comparing expressions (r) and (s) reveals that if $R'_1 = R_1$, $R'_2 = R_2$ and $R_s = 2R'_s$, the power attenuation of the circuits in figure 4 and figure 6 are identical. This agrees with R.I. Gray's conclusions in his note (see appendix) on the use of attenuators in balanced and unbalanced networks.

4.3.15 In effect, the curves in figure 13 are identical to those for the single unit except that the abscissa (the nC scale) is multiplied by a factor of 1/2. That this should be so is apparent when figure 5, which is the circuit for the double unit, is compared with figure 6 which is the circuit for the single unit. These curves give all possible solutions to a π network with a 0.75 ohm load connected in parallel with it being supplied with a voltage source of 28 volts and an internal resistance of 5 ohms. Intermediate intersection points can always be interpolated.

4.3.16 There are definite relationships between circuit parameters that will give the minimum power attenuation. This minimum exists when the combined resistance of the π network connected in parallel with the load resistance is equal to the load resistance. Under these conditions the input current has the following value $I_1 = (E)/(R_s + R_g) = (28)/(.75+5.00) = 4.86956$. This value of input current has been plotted on the curves of figure 13. Therefore it is possible for a given K and C to determine the length of cable n that will give the minimum power attenuation.

4.3.17 The fact that minimum power attenuation is achieved when the total resistance equals the load resistance has been confirmed by minimizing expression (r) for power attenuation. The following expression is the result and gives the length which will result in minimum power attenuation in a double unit:

$$\text{(t)}\quad [n]_{\text{MIN POWER ATT.}} = \frac{Rs}{K}\sqrt{\frac{K}{C} + 1}$$

The corresponding expression for a single unit is -

$$\text{(u)}\quad [n']_{\text{MIN POWER ATT.}} = \frac{2Rs'}{K'}\sqrt{\frac{K'}{C'} + 1}$$

It should be noted that the length required for a double unit is one-half that required for a single unit if the load, the resistance per ft. of the outer conductor, and the resistance per ft of the inner conductor are identical in both cases. The same conclusion must be drawn when comparing figure 6 with figure 5.

4.3.18 To determine the absolute minimum power attenuation for a particular K/C, expression (t) may be substituted into expression (r) and expression (u) may be substituted into expression (s). Utilizing expressions (f) and (g) and using primes to distinguish between values in the single unit and the double unit, the expressions for minimum power attenuation become -

(v) MIN POWER ATTENUATION DOUBLE UNIT (db)

$$= 10 \log \left\{ 1 + \left[\frac{8\left(\frac{K}{C} + 1\right) + 4\left(\frac{K}{C} + 2\right)\sqrt{\frac{K}{C} + 1}}{\left(\frac{K}{C}\right)^2} \right] \right\}$$

(w) MIN. POWER ATTENUATION SINGLE UNIT (db)

$$= 10 \log \left\{ 1 + \left[\frac{8\left(\frac{K'}{C'} + 1\right) + 4\left(\frac{K'}{C'} + 2\right)\sqrt{\frac{K'}{C'} + 1}}{\left(\frac{K'}{C'}\right)^2} \right] \right\}$$

4.3.19 If the load, the resistance per ft. of outer conductor and the resistance per ft. of inner conductor in the single unit and double unit are identical and the double unit length is half that of the single unit length, the minimum power is the same. This is the only point at which the power attenuation is the same because at all other points expressions (r) and (s) must be used. Again this is confirmed by comparing figures 5 and 6 which emphasize the point that the total length used in both cases is the same and that the double unit has half as much wire in each branch (see figure 4) as the single unit.

4.3.20 Additional restrictions on the relationships between the circuit parameters are imposed by the cable geometry (see figure 7). Since RF attenuation is a function of outer conductor thickness t_K= in.), a relationship between the grouped parameter $\left[\frac{K}{C}\right]$ the resistance per foot of the inner conductor (C), and t_K is derived. Since the coaxial cable consists of an inner conductor, a layer of insulation, and the outer conductor, the cross sectional area of the outer conductor may be expressed as -

(x) $A_K = \pi (r_3^2 - r_2^2)$

However, r_3 and r_2 may also be expressed as -

(y) $r_3 = r_1 + t + t_K$

and -

(z) $r_2 = r_1 + t$

The resistivity of the outer conductor may be expressed as -

(aa) $\rho_K = KA_K$

and the resistivity of the inner conductor may be expressed as -

(bb) $\rho_C = C\pi r_1^2$

Combining results from expressions (x) through (bb) and rearranging terms, the following expression is derived -

$$(cc) \quad \frac{\boxed{K}}{\boxed{C}} = \frac{\rho_K}{\boxed{C}} \left(\frac{1}{M + \sqrt{\frac{\boxed{N}}{\boxed{C}}}} \right)$$

where in the interest of brevity -

(dd) $M = \pi t_K (2t + t_K)$

(ee) $N = 4\pi \rho_C t_K^2$

4.3.21 The units of resistivity ρ are ohms - in. ^{2}/ft. so that t and t_K are thicknesses in inches and C is ohms/ft. Expression (cc) makes it possible to plot $\boxed{K}$ as a function of C with t, ρ_K and ρ_C as fixed parameters. Figure 14 is a plot of this expression when t_K is fixed at .004 in. wall, ρ_C is fixed at the resistivity of copper, ρ_K is fixed at 5.197×10^{-5} as the resistivity of 99% iron, as specified by the supplier, and insulation is fixed at .001 in. and .002 in. providing the two curves shown. The plots of this expression in previous reports gave the resistivity of 99% iron and SAE 1010 steel as being the same. Actually the iron has less resistivity (6.614×10^{-5} vs 5.197×10^{-5}). These physical properties have not been confirmed.

Attempts are being made to tighten control of the physical tolerances on the cable geometry parameters so that the circuit characteristics, i.e., output current and attenuation, can be confined to the narrowest practical limits.

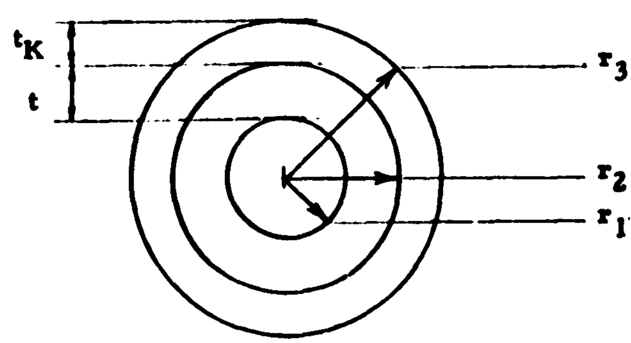


Figure 7

4.4 Testing

4.4.1 The evaluation of the eight groups of RIG devices was done in accordance with specification L-19910-67 (see appendix) as follows:

a. To determine power attenuation from a frequency range of 200 cycles per second to 1 megacycle.

b. To determine the DC attenuation of each device.

c. To measure the DC heat rise of one device in each group, varying the DC power input until a maximum surface temperature at 300°F is obtained.

d. To note RF attenuation capabilities at 10 and 100 megacycles of one device in each group with varying RF power dissipation until a maximum surface temperature of 300°F is obtained.

e. To determine environmental resistance under conditions specified in the L-19910-67 specification. (See appendix for copy of specification and addendum.)

4.5 Test Procedures

4.5.1 General - For all tests the RIG devices were terminated in a 0.75 ohm resistive load. The load resistors were constructed using the methods given in MIL-STD-220, "Method of Insertion - Loss Measurement for Radio Frequency Filters". The same load resistor was used for all measurements on a given serial number device.

4.5.2 Voltage Measurements - The voltage level into all devices under test was held constant at 0.5 volts RMS from 0.2 to 600 kilocycles and 1.0 volt RMS from 700 to 1000 kilocycles. The output voltage across the 0.75 ohm load resistor was noted at test frequency points from 0.2 to 1000 kilocycles. All devices were then reversed, end for end, and the test points repeated with the same input voltage levels applied as stated above.

4.5.3 Impedance Measurements (0.2-100 KC.) The signal generator voltage into the bridge for all tests was 0.5 volt RMS from 0.2 to 100 kilocycles. The Stoddart Model NM-10A receiver was used as a two terminal voltmeter-null detector from 20 to 100 kilocycles. Impedances were read with the devices terminated in 0.75 ohms resistive. The devices were turned end for end and the impedances were repeated throughout the same frequency spectrum.

4.5.4 Impedance Measurements (100-1000 KC.) The signal generator voltage into the bridge was as follows: 0.5 volts RMS, 100 to 600 kilocycles; and 1.0 volt RMS, 700 to 1000 kilocycles. The devices were terminated in 0.75 ohms resistive and the impedances were read from each end of the devices.

4.5.5 DC Attenuation Test - The volt-amp. method was used to determine the power into the device. The voltage developed across the 0.75 ohm resistor was used to calculate the power out of the device. The power level into the device was held to a low value to prevent the effects such as resistance change due to heat from influencing the DC attenuation tests. This was done to correlate the data with the low frequency RF attenuation tests which were also performed at low power levels. DC attenuation tests were performed on each device with power applied to one end and then turning the device end for end and repeating the tests described above.

4.5.6 DC Heat Rise - One device from each group was subjected to DC heat rise tests. The devices were terminated in a 0.75 ohm 100 watt wire wound resistor. The power into the device was applied in increasing steps. The temperature on the outer skin of the device was monitored. The difference in the power applied and the power consumed in the 0.75 ohm resistor constituted the power dissipated in the device. The dissipated power was increased until a maximum of 300°F was recorded at the devices skin surface.

4.5.7 RF Test (10 and 100 Megacycles) - The RF power at 10 and 100 megacycles was applied to one device of each group. The devices were terminated in the 0.75 ohm resistive coaxial resistor. The input power level was established by observing the incident and reflected power on the MicroMatch meter. The matching network was adjusted until the reflected power was zero or to a minimum value approaching zero. The VSWR for all tests approached a value of 1. The heat rise on the skin of the device was noted by a thermocouple attached to a fill hole as in the DC heat rise tests. This temperature rise was recorded at varying power input levels until a temperature approaching 300°F was again noted on the skin of the device. The output voltage level was also noted across the 0.75 ohm resistor at each frequency and at each power level. This voltage was read on the Empire NF-105 field intensity meter set on the carrier function. The instruments output meter was calibrated for full scale deflection as a two terminal voltmeter.

4.6 RF Test Results

4.6.1 Figure 8 is a composite curve of all types of RIG devices tested to date. It includes both double unit and single unit types. Also included in figure 8 is the attenuation curve for the .0015 in. 1010 steel, L-19910-36 RIG tested in Phase I. The tabulations of the attenuation vs. frequency of all the devices tested are included in the appendix (see Tables V through XIII).

4.6.2 Figure 9 is a comparison of 1010 steel, 99% iron, and No. 42 alloy, assuming a constant material wall thickness of .0015 in. The 1010 steel gave the highest RF attenuation with the 99% iron next and the No. 42 alloy the least.

4.6.3 Figure 10 is similar to figure 9 except that the wall thickness in the case of 1010 steel, 99% iron, and 42 alloy is assumed to be .003 in. These results show the 99% iron to be the superior in RF performance with respect to the 1010 steel and the No. 42 alloy.

4.6.4 The apparent conflict between figures 9 and 10 can only be attributed to the inability of accurately determining the actual tube wall thickness of the .0015 in. material. The tolerance of $\pm$ .0005 in. could make as much as a .001 in. discrepancy between any two materials. For this reason the 99% iron is believed to provide superior RF attenuation.

4.6.5 Figure 11 is a comparison of various wall thicknesses for RIG's manufactured from 99% iron. Both the .004 in. and the .005 in. wall thicknesses meet the 40 db power attenuation requirements at 100 kilocycles.

4.6.6 Figure 12 compares various wall thicknesses for No. 42 alloy manufactured into RIG devices. None of these devices met the 40 db power attenuation requirements of 100 kilocycles.

4.7 DC Attenuation Results

4.7.1 The DC power attenuation for all RIG devices tested is included in Table II of the Appendix. A summary is included in Table I.

4.7.2 The only device to approach the DC and RF attenuation requirements was the unit having the .004 in. 99% iron wall in the 66-1 group of Table II. The 66-1 group had a DC power attenuation of 8.1 db.

4.7.3 The spread between the maximum and minimum values in DC attenuation as noted in Table I may be due, in part, to the fact that the cable lengths were not exactly the same length for devices of the same construction.

4.8 DC Heat Rise Results

Table III of the Appendix gives the results of the DC heat rise tests for each group of RIG devices. None of the single unit devices was capable of dissipating 10 watts of power prior to obtaining a surface temperature of 300°F. The -66 and -66-1 groups were capable of dissipating the highest power levels which was approximately 8 watts.

4.9 AC Heat Rise Results

4.9.1 All single unit devices were capable of withstanding similar magnitudes of AC power at 10 and 100 megacycles as those listed in the DC heat rise results. No device malfunctions occurred after 1 hour exposure to this heating.

4.9.2 No double unit devices were tested for AC heat rise due to the difficulty encountered in matching the double unit devices to the single ended transmitters.

4.10 10 and 100 Megacycle Attenuation

Table IV of the Appendix shows that all devices tested continued to attenuate RF power at these two frequencies. Where the detectable level across the 0.75 ohm resistor fell below an indicated 1 microvolt level reading, any reading obtained was considered inaccurate.

4.11 Firing Current Response Time

Two -66-1 RIG devices were tested for response time by monitoring the delay time between application of power to the input of the device and development of 1.5 amps firing current in a .75 ohm resistance load. The delay time was approximately .7 milliseconds. The two units tested were s/n 153 and 157.

4.12 Environmental Testing

4.12.1 The following RIG devices were submitted to the Engineering Test Laboratory for environmental tests:

Part No.	Serial Nos.
L-19910-49-1	71 and 73
L-19910-49-2	92 and 94
L-19910-49-3	35 and 45
L-19910-49-4	18 and 19
L-19910-49-5	117 and 118
L-19910-66	54 and 62
L-19910-70	127/128 and 133/134

4.12.2 Each of the RIG devices was subjected to the following environmental tests in accordance with Specification L-19910-67 of issue in effect on date of inception of these tests.

1. Initial Resistance and Inductance Measurements (3.4.1 and 3.4.2.)
2. High Temperature Tests (4.1)
3. Low Temperature Tests (4.2)
4. Thermal Shock (4.3)
5. Vibration (4.6)
6. Shock (4.7)
7. Humidity (4.4.)
8. DC Temperature Rise (4.8)
9. AC Temperature Rise (4.10)
10. Terminal Pull (4.9)
11. Salt Spray (4.5)

4.12.3 Each of the RIG devices met all of the requirements of the foregoing tests with the following exceptions. Unit serial number 73 did not perform satisfactorily during the AC Temperature Rise Test. It appeared to have a short in the windings. The unit was disassembled at the conclusion of all the tests. The coaxial wire was unsoldered and resistance measurements of the center conductor and the outer conductor were made. The coaxial wire was re-soldered at each end and resistance measurements were made and compared to the individual values of the conductors. There was no indication of a short in the windings. Further investigation of the discrepancy failed to reveal any additional evidence of the cause.

4.12.4 Unit serial number 118 exhibited erratic resistance readings following the Humidity Test and the inductance measurements could not be made. This unit was subjected to the balance of the environmental tests and then submitted to the Research Laboratory for investigation.

4.12.5 The two pin connector on the output end on each of two of the double unit RIG devices became damaged during testing. In both instances the damage resulted from shearing of the small key in the shell during tightening of the coupling ring. The pins were sheared off flush with the face of the insert, rendering the connector useless. The key in the shell of the receptacle is formed by upsetting the shell wall and is apparently far too weak to adequately perform its intended function.

4.13 <u>Retest of RIG 118.</u>

This test consisted of impedance and voltage measurements to verify the results in paragraph 4.12.4. The device as received was erratic in behavior with respect to impedance measurements. The open circuit input impedance of the No. 2 end appeared to be twice that of the No. 1 end. The device was retested again after a lapse of several days. The device then tested normal for both impedance and RF measurements. Striking the device in a sharp manner produced no erratic behaviors. The device is still under investigation with as yet no cause determined for the original malfunction.

5.0 <u>Conclusions</u>

5.1 The double unit circuit as shown in figure 4 is the same circuit as shown in figure 5 when it is perfectly balanced. This circuit is basically the same as that of the single unit shown in figure 6. Therefore the design curves shown in figure 13 are the same as those for a single unit except for one feature. The abscissa (the nC scale) is multiplied by a factor of 1/2 in the new curves. The conditions for minimum power attenuation were also investigated for both single and double units. The length n that gives

minimum attenuation is given in expressions t and u, paragraph 4.3.17. The minimum power that can be attained with a particular set of parameters is given in expressions v and w, paragraph 4.3.18. These conditions are achieved when the load and the π network are matched; i.e., when the combined input resistance of the π network and the load is equal to the load resistance.

5.2 The test results show the .004 in. wall 99% iron (group-66-1) devices to be those which most nearly comply with the general requirements for the RIG.

5.3 The environmental testing resulted in erratic electrical behavior of two units but there was not sufficient evidence to warrant attributing these malfunctions to environmental stress.

6.0 Recommendations

It is recommended that the .004 in. wall 99% iron single unit design be manufactured for Phase III of the program. This recommendation is based upon the general requirements and conclusions as stated.

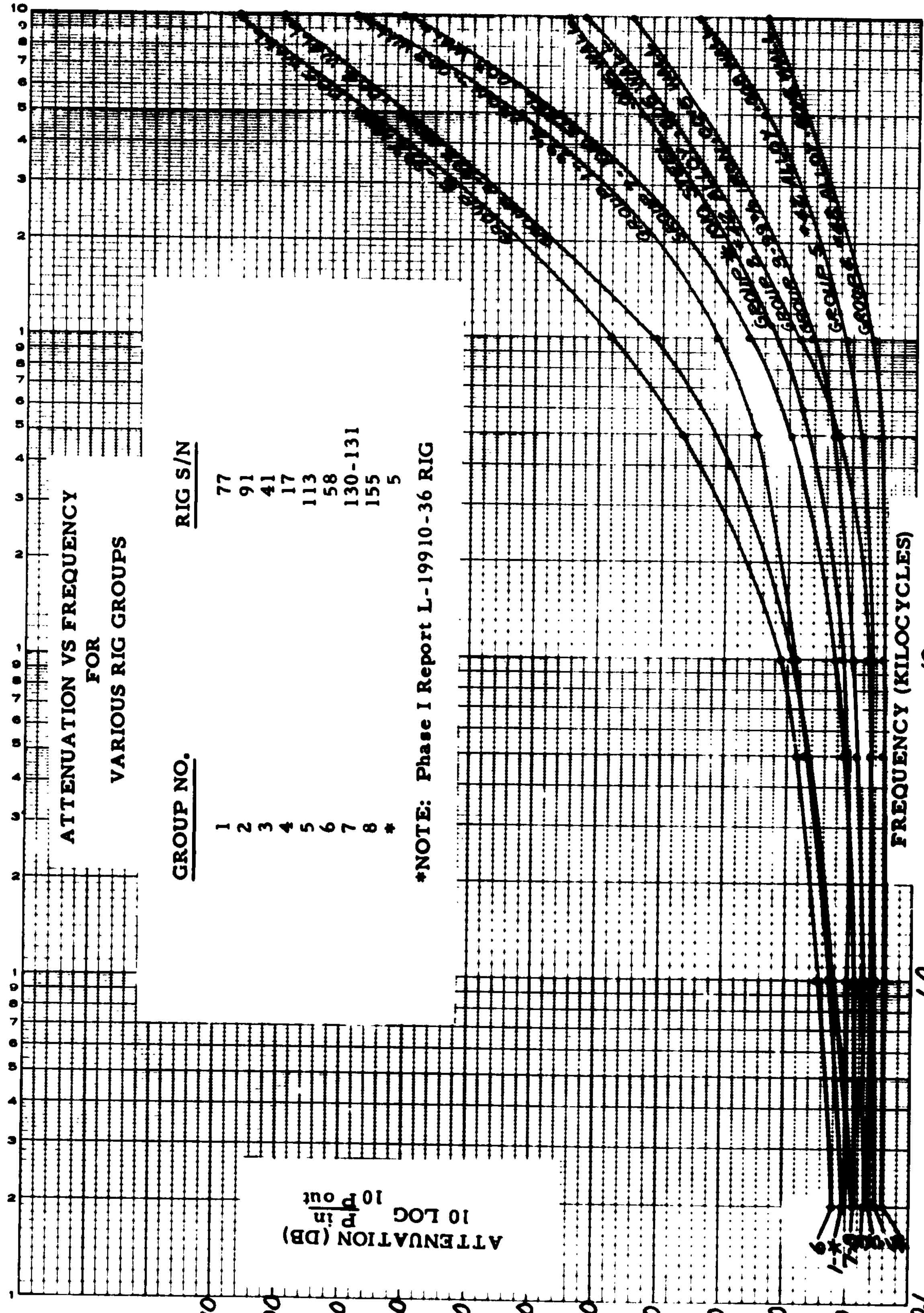
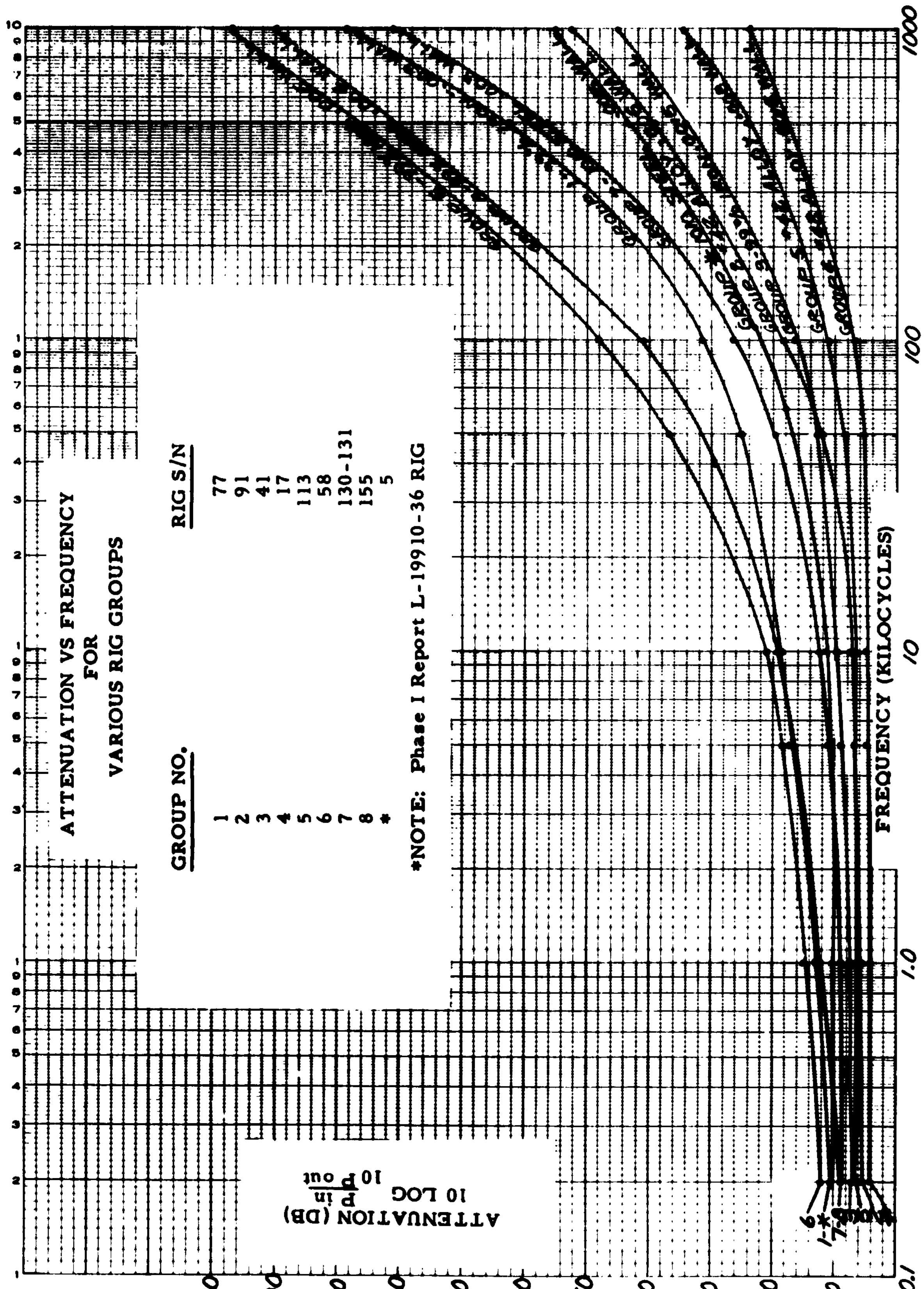
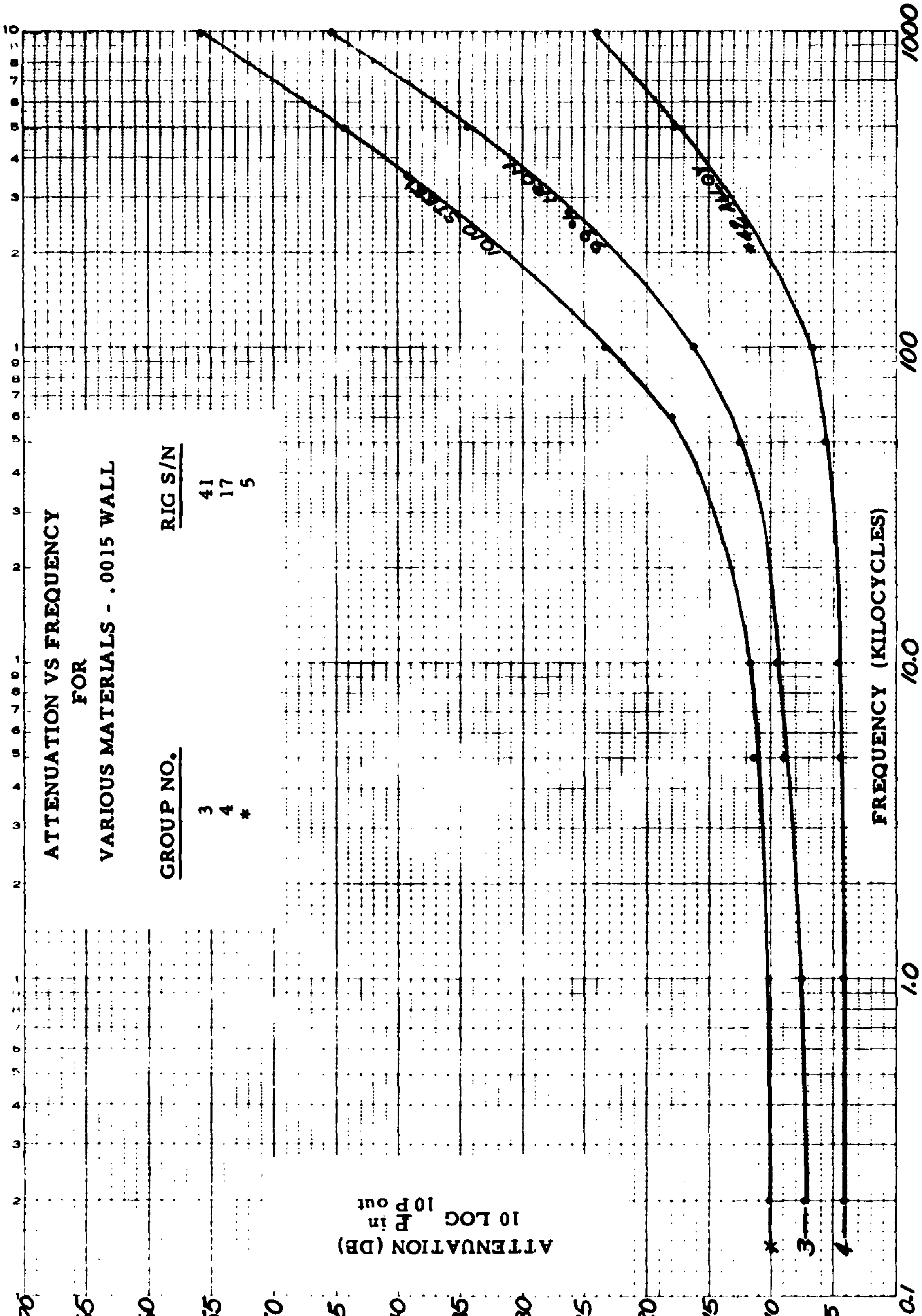

ATTENUATION VS FREQUENCY
FOR
VARIOUS RIG GROUPS
GROUP NO.
RIG S/N
1 77
2 91
3 41
4 17
5 113
6 58
7 130-131
8 155
* 5
*NOTE: Phase I Report L-19910-36 RIG
FREQUENCY (KILOCYCLES)
ATTENUATION (DB)
10 LOG 10 P in / P out
0.1
1.0
10
100
1000
10
20
30
40
50
60
70
80
90
100
110

Figure 8



ATTENUATION VS FREQUENCY
FOR
VARIOUS RIG GROUPS
GROUP NO.
1
2
3
4
5
6
7
8
*
RIG S/N
77
91
41
17
113
58
130-131
155
5
*NOTE: Phase I Report L-19910-36 RIG
ATTENUATION (DB)
10 LOG $_{10}\frac{P_{in}}{P_{out}}$
FREQUENCY (KILOCYCLES)
0.1
1.0
10
100
1000
110
100
90
80
70
60
50
40
30
20
10
0

Figure 8



ATTENUATION VS FREQUENCY
FOR
VARIOUS MATERIALS - .0015 WALL
GROUP NO.
3
4
*
RIG S/N
41
17
5
1010 STEEL
99.9% IRON
*48% Ni.01
ATTENUATION (DB)
10 LOG 10 P in / P out
FREQUENCY (KILOCYCLES)
0.1
1.0
10.0
100
1000
70
65
60
55
50
45
40
35
30
25
20
15
10
5

Figure 9

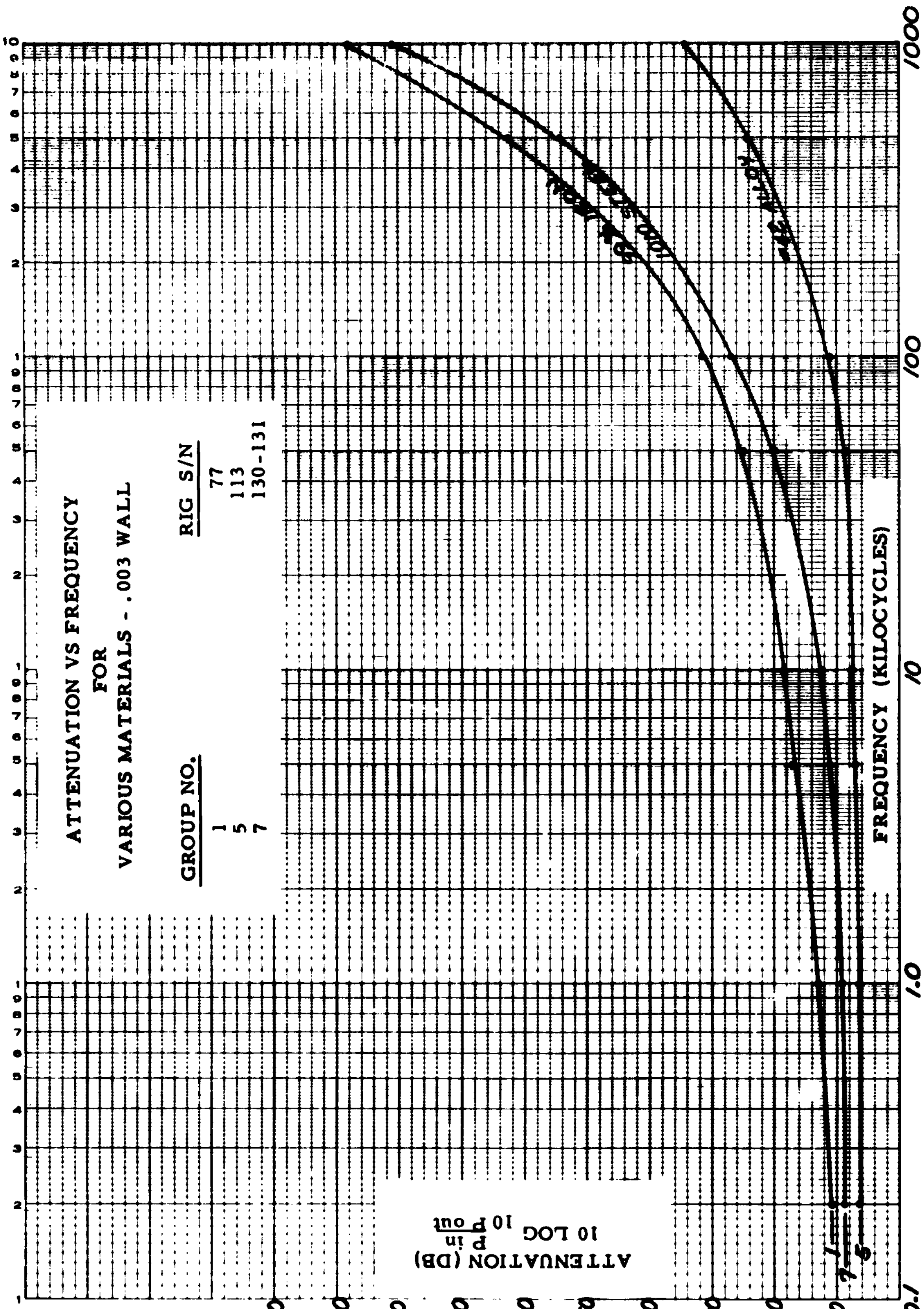

ATTENUATION VS FREQUENCY
FOR
VARIOUS MATERIALS - .003 WALL
GROUP NO.
1
5
7
RIG S/N
77
113
130-131
FREQUENCY (KILOCYCLES)
ATTENUATION (DB)
10 LOG $_{10}$ $\frac{P_{in}}{P_{out}}$

Figure 10

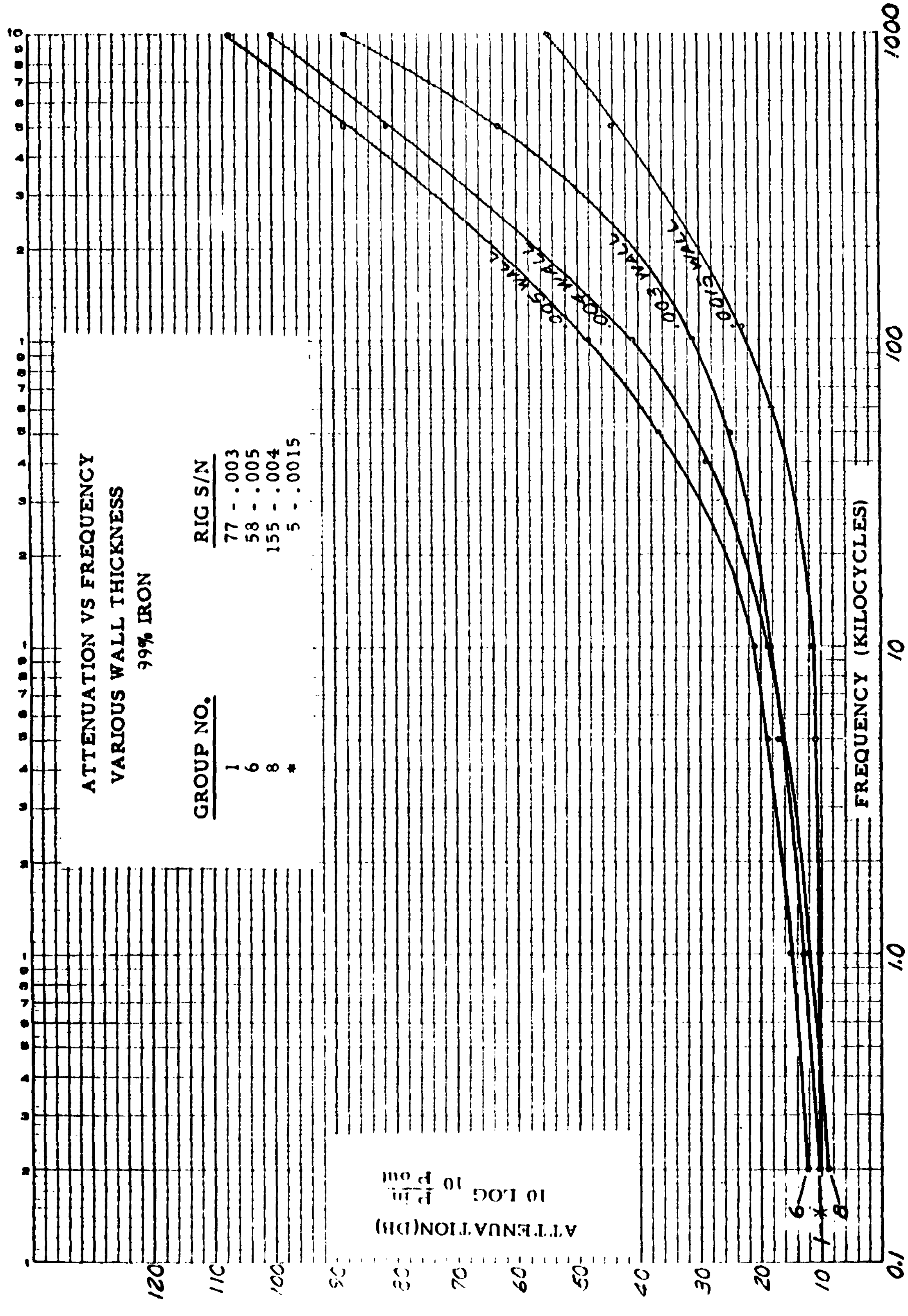

ATTENUATION VS FREQUENCY
VARIOUS WALL THICKNESS
99% IRON
GROUP NO.
1
6
8
*
RIG S/N
77 - .003
58 - .005
155 - .004
5 - .0015
.005 WALL
.004 WALL
.003 WALL
.0015 WALL
ATTENUATION(DB)
10 LOG10 Pin/Pout
FREQUENCY (KILOCYCLES)
0.1
1.0
10
100
1000
10
20
30
40
50
60
70
80
90
100
110
120

Figure 11

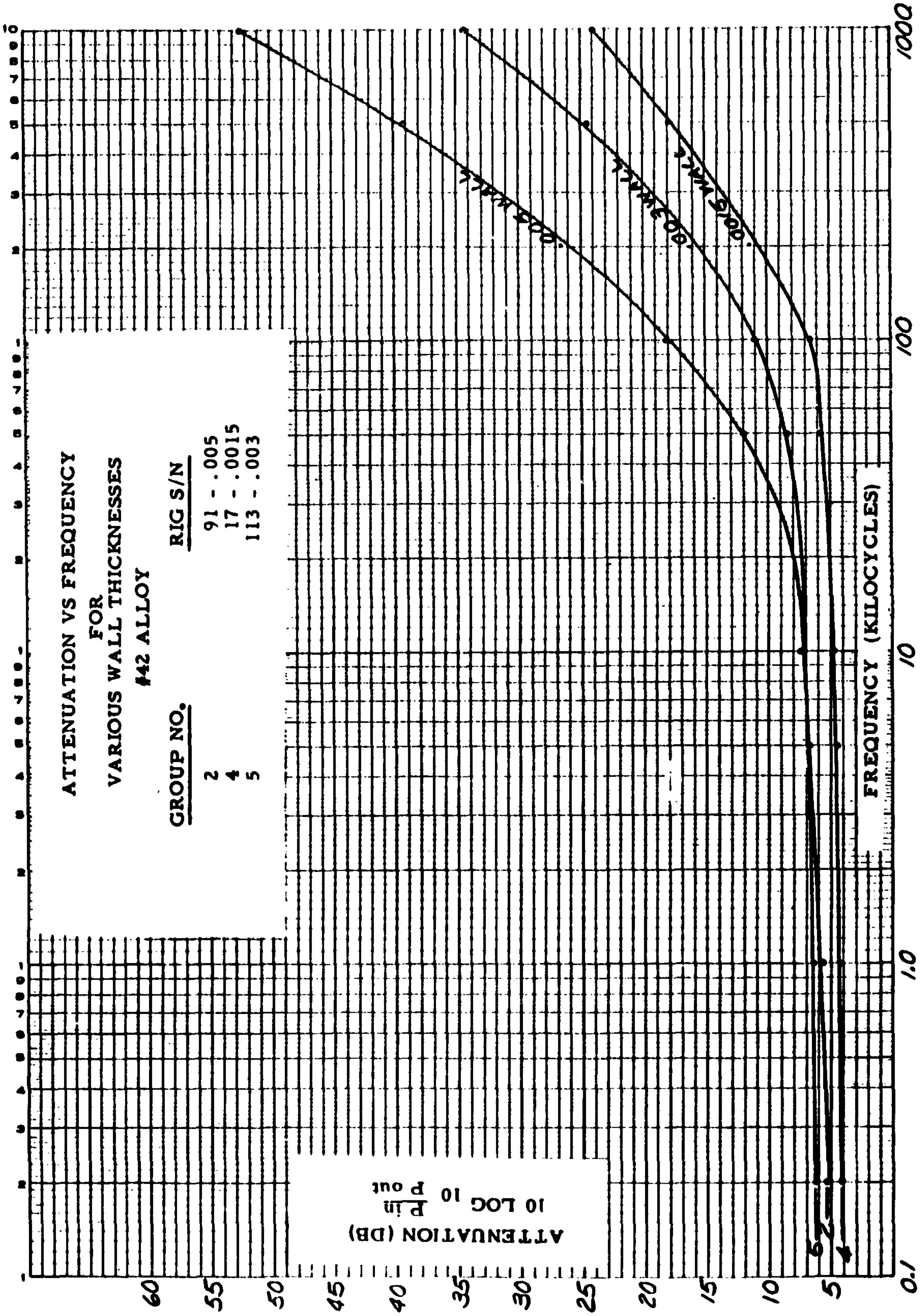
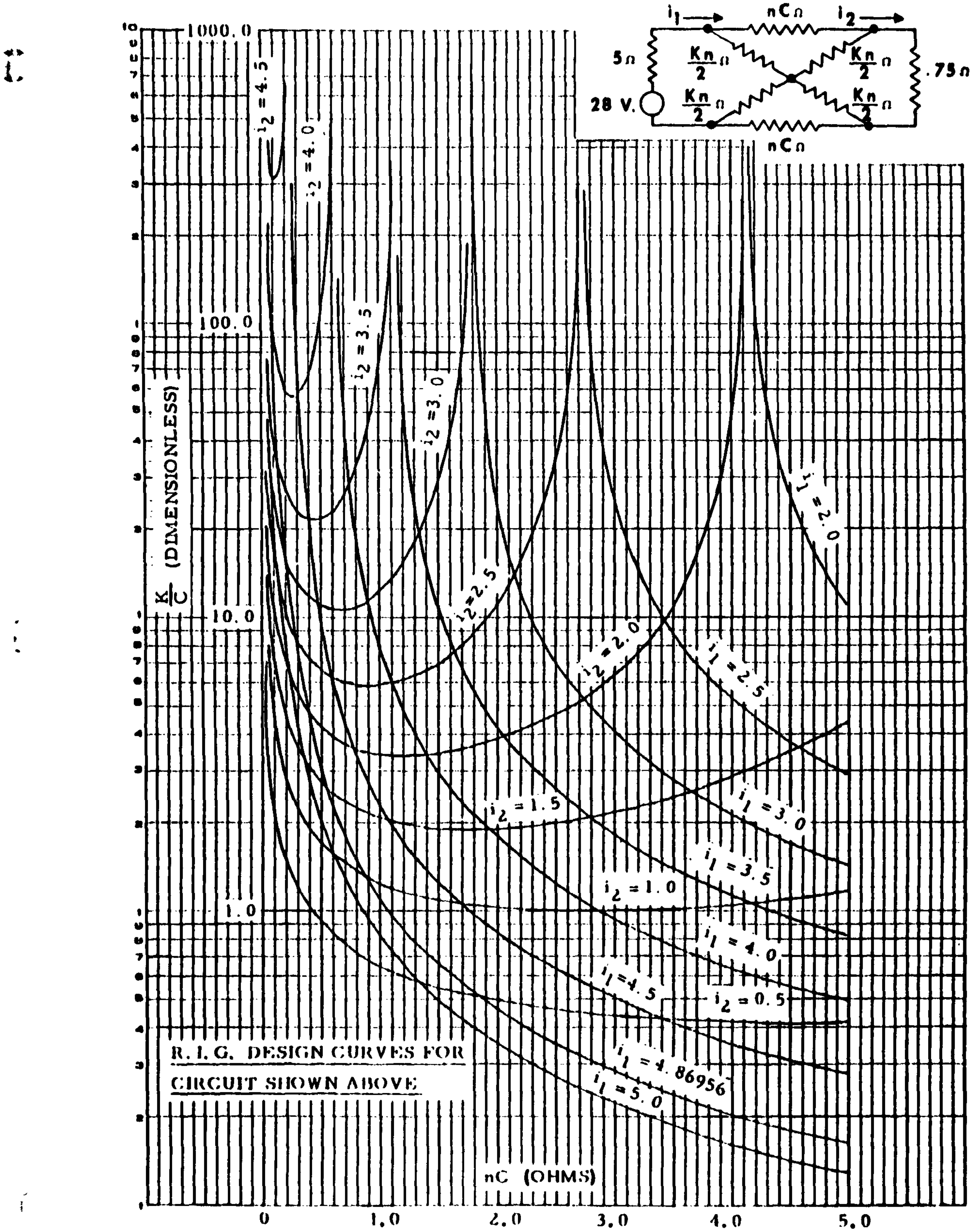
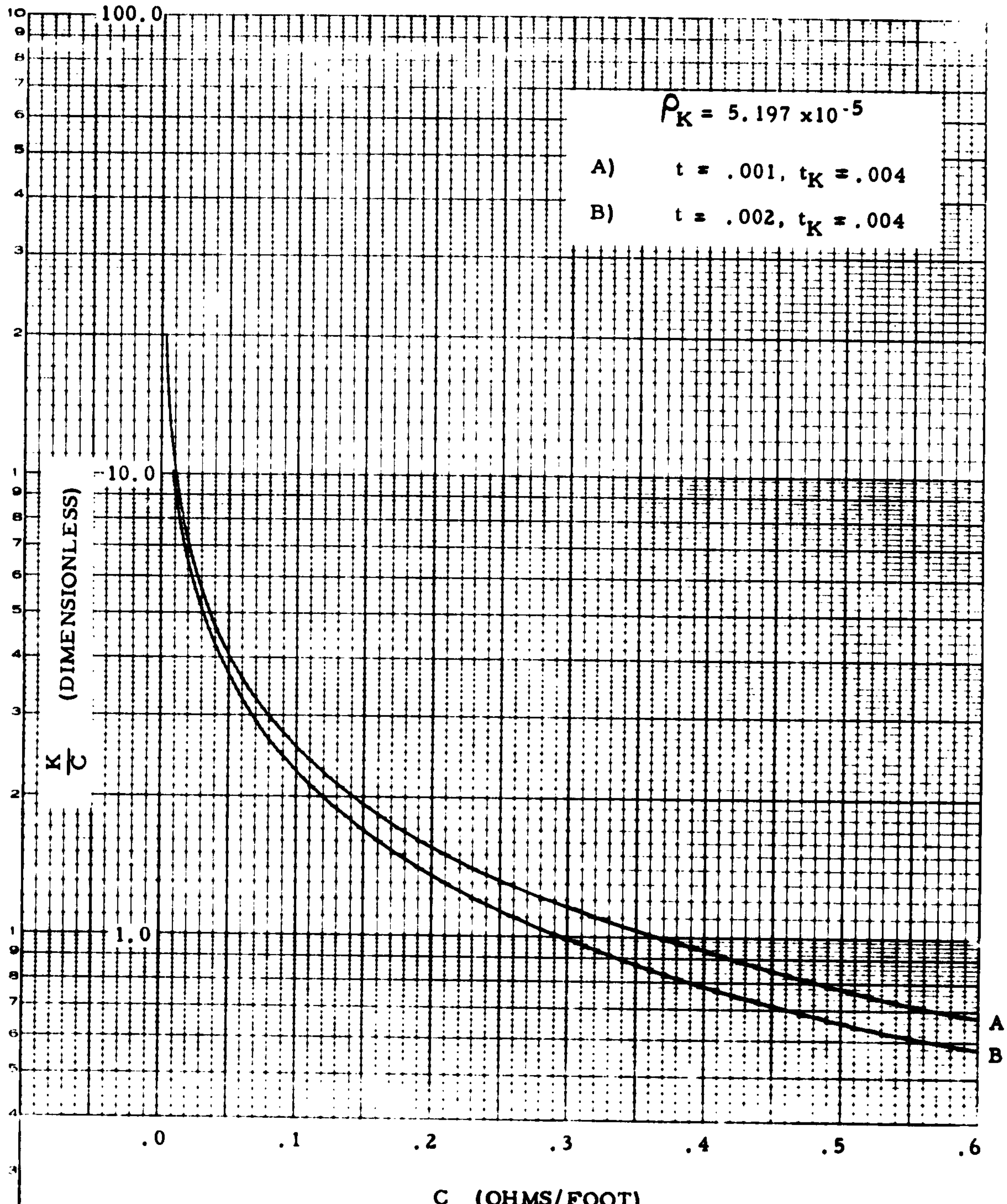

ATTENUATION VS FREQUENCY
FOR
VARIOUS WALL THICKNESSES
#42 ALLOY
GROUP NO.
RIG S/N
2
4
5
91 - .005
17 - .0015
113 - .003
FREQUENCY (KILOCYCLES)
ATTENUATION (DB)
10 LOG 10 P in / P out
0.1
1.0
10
100
1000
60
55
50
45
40
35
30
25
20
15
10
5

Figure 12



RIG Design Curves

Figure 13



RELATIONSHIP BETWEEN $\left[\frac{K}{C}\right]$ AND C IN A COAXIAL CABLE OF CIRCULAR CROSS-SECTION (SEE FIGURE 7)

RIG Design Curves

Figure 14

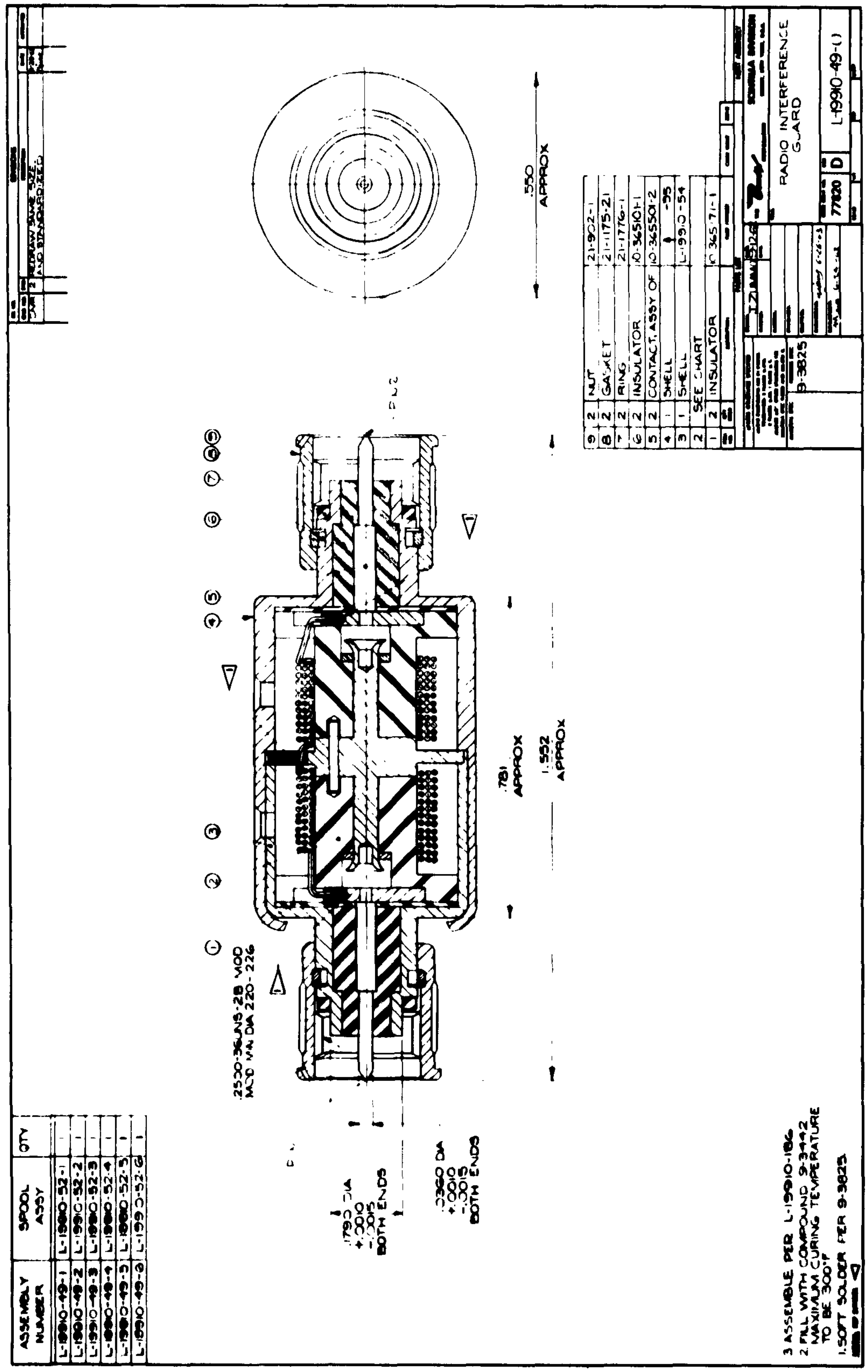

RADIO INTERFERENCE GUARD
L-19910-49-( )
9-3825
NUT
GASKET
RING
INSULATOR
CONTACT, ASSY OF
SHELL
SEE CHART
.550 APPROX
.781 APPROX
1.552 APPROX
3 ASSEMBLE PER L-19910-186
2 FILL WITH COMPOUND 9-3442 MAXIMUM CURING TEMPERATURE TO BE 300°F
1 SOFT SOLDER PER 9-3823

Figure 15

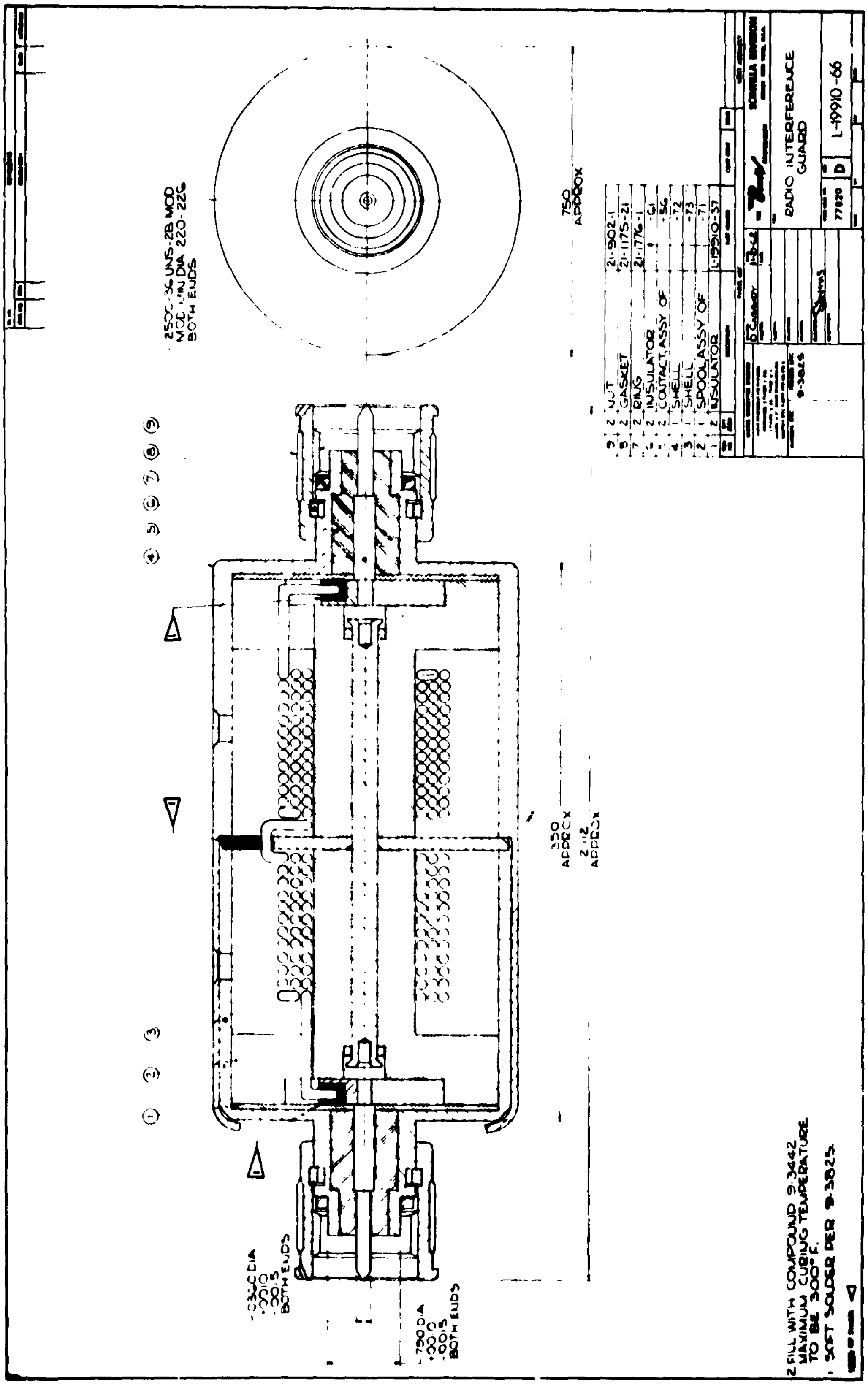

RADIO INTERFERENCE GUARD
L-49910-66
D
9 2 NUT 21-902-1
8 2 GASKET 21-1175-21
7 2 RING 21-1776-1
6 2 INSULATOR -61
5 2 CONTACT, ASSY OF -56
4 1 SHELL -72
3 1 SHELL -73
2 1 SPOOL ASSY OF -71
1 2 INSULATOR L-19910-37
.750 APPROX
.350 APPROX
2.12 APPROX
2 FILL WITH COMPOUND 9-3442 MAXIMUM CURING TEMPERATURE TO BE 300°F.
1 SOFT SOLDER PER 9-3825.

Figure 16

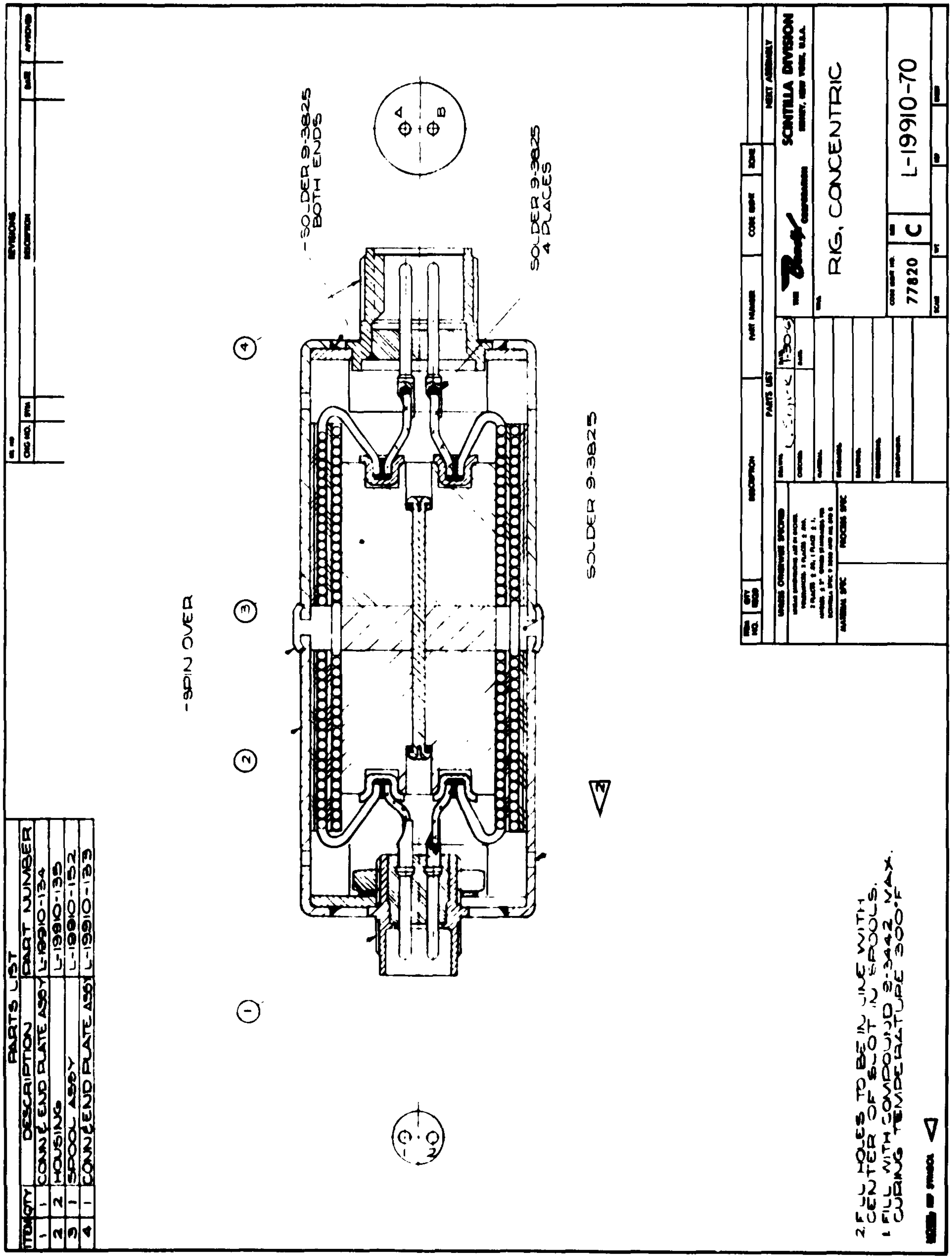

PARTS LIST
ITEM QTY DESCRIPTION PART NUMBER
1 1 CONN & END PLATE ASSY L-19910-134
2 2 HOUSING L-19910-135
3 1 SPOOL ASSY L-19910-152
4 1 CONN & END PLATE ASSY L-19910-133
SOLDER 9-3825 BOTH ENDS
SOLDER 9-3825 4 PLACES
SOLDER 9-3825
SPIN OVER
2 FILL HOLES TO BE IN LINE WITH CENTER OF SLOT IN SPOOLS.
1 FILL WITH COMPOUND 3-3442 MAX. CURING TEMPERATURE 300°F
SCINTILLA DIVISION
RIG, CONCENTRIC
77820
C
L-19910-70

Figure 17

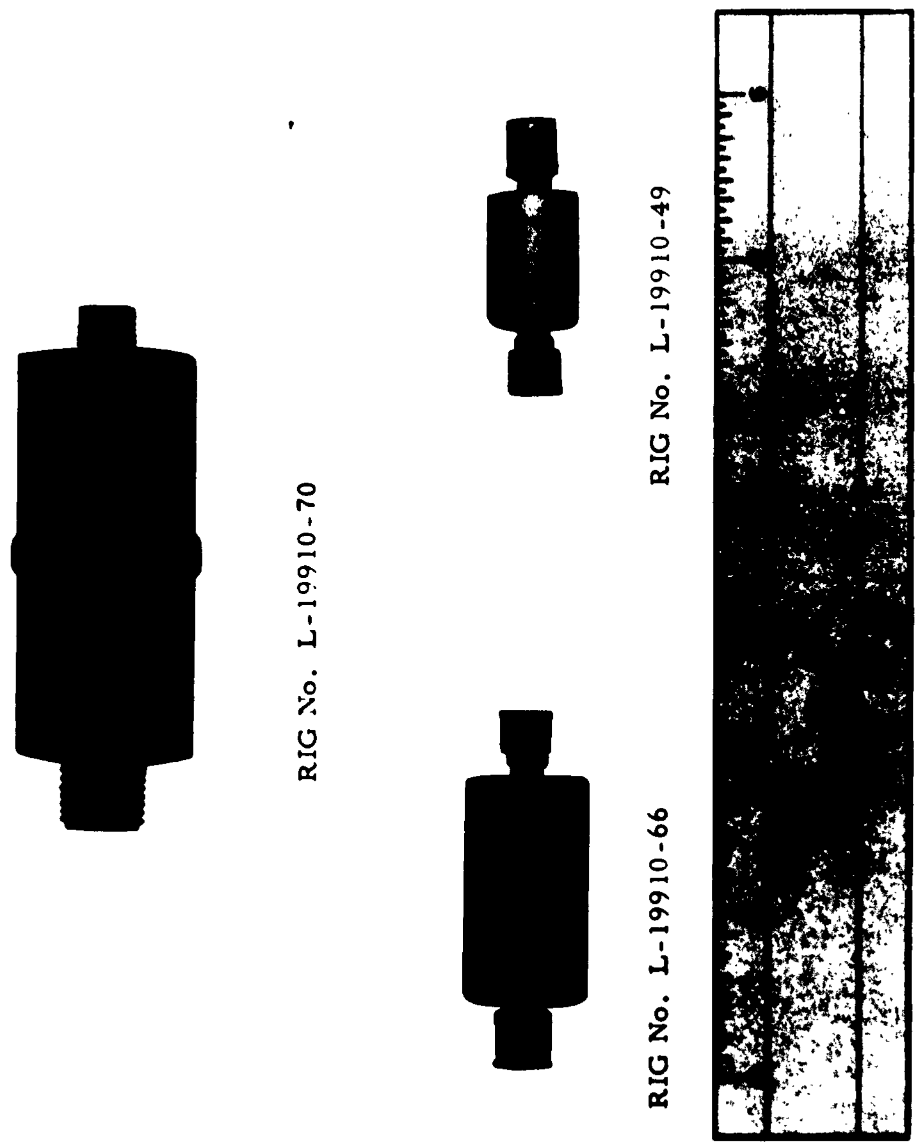


Figure 18

Appendix

Contents:

Formulae

Computations - Power and Voltage Attenuation .2 to 1000 kilocycles

Power attenuation in db = $10 \log_{10} \frac{P_1}{P_2}$

P_1 = power into the device in watts

P_2 = power out of the device in watts

$P_1 = \frac{(E_{in})^2}{Z_{in}}$ where $Z_{in} = R_s + J X_s$

R_s is the bridge measured resistive component of the input impedance in ohms, with the device terminated in 0.75 ohms resistive.

X_s is the bridge measured inductive reactive component of the input impedance in ohms, with the device terminated in 0.75 ohms resistive.

$$P_1 \text{ real} = \frac{(E_{in})^2 R_s}{(R_s)^2 + (X_s)^2}$$

$P_2 \text{ real} = \frac{(E_{out})^2}{R_L}$ where R_L is constructed to be 0.75 ohms resistive from .2 to 1000 kilocycles

Therefore, the power attenuation is equal to:

$$10 \log_{10} \frac{(E_{in})^2 R_s R_L}{(E_{out})^2 \left[(R_s)^2 + (X_s)^2\right]}$$

$$db = 20 \log_{10} \frac{E_{in}}{E_{out}} + 10 \log_{10} \frac{R_s R_L}{(R_s)^2 + (X_s)^2}$$

Limitations of formula:

at low frequencies, from .2 to 10 kilocycles, where X_s is small and R_s is less than 1 the power DB appears to be greater than the voltage DB. This is due to the fact that the $10 \log_{10}$ factor of the formula is greater than 1 and is positive.

Computations - DC Attenuation

$$\text{DC power attenuation} = 10 \log_{10} \frac{P_1}{P_2}$$

$$P_1 = E_{in} \times I_{in}$$

$$P_2 = \frac{(E_{out})^2}{R_L} \text{ where } R_L = 0.75 \text{ ohms}$$

$$\text{DC attenuation in db} = 10 \log_{10} \frac{E_{in} \times I_{in} \times R_L}{(E_{out})^2}$$

Table I

GROUPS		1	2	3	4	5	6	7	8
Drawing No. L-19910-		49-1	49-2	49-3	49-4	49-5	66	70	66-1
Inner Conductor	AWG Size	30	30	32	32	35	28	30	26
	Diameter Over Insulation (in.)	.013	.013	.009	.009	.008	.016	.014	.019
Outer Conductor	O.D. (in.)	.018	.023	.012	.012	.014	.026	.020	.027
	Wall thickness (in.)	.003	.005	.0015	.0015	.003	.005	.003	.004
	Material	99% Iron	#42 Alloy	99% Iron	#42 Alloy	#42 Alloy	99% Iron	1010 Steel	99% Iron
Pre-fabricated* N=Length of Coax in RIG (ft.)		4.5	4	6	6	3	9.5	9	12
Measured DC Power (DB)	Max.	10.31	5.42	7.52	4.13	6.76	11.54	9.56**	8.16
	Min.	9.62	5.34	6.03	3.82	6.28	10.80	9.24	7.96

*Figure is approximation of actual length in units and includes cut off during fabrication

**Overall attenuation including both circuits

Table II

Test D.C. POWER ATTENUATION	Spec.	Para.
Test Instrument(s)		Date
		R Load =

GROUP NO.	SERIAL NO.	ATTEN. (DB)		GROUP NO.	SERIAL NO.	ATTEN (DB)	
49-1	71	10.13		-66-1	150	8.11	
	77	9.90			151	8.07	
	78	9.62			153	8.16	
	79	10.31			154	7.96	
					155	8.06	
49-2	91	5.42			157	8.14	
	92	5.36					
	94	5.34		-70	121-122		
	95	5.34			SECTION A-1	9.63	
					SECTION B-2	9.32	
49-3	35	7.45			BOTH	9.24	
	41	7.44					
	42	6.03			124-125		
	43	6.81			SECTION A-1	8.98	
	45	7.52			SECTION B-2	9.34	
					BOTH	9.56	
49-4	17	4.10					
	18	4.13			130-131		
	19	3.82			SECTION A-1	9.98	
	24	4.13			SECTION B-2	9.00	
	25	4.03			BOTH	9.51	
49-5	113	6.33					
	114	6.28					
	115	6.36					
	117	6.35					
	118	6.76					
-66	52	10.8					
	56	11.18					
	58	11.18					
	54	11.26					
	62	11.54					

Appendix

Table III

TEST D.C. HEAT RISE	SPEC.	PARA.	ECL
TEST SPECIMEN	DATE	TEMP.	RH.
TEST INSTRUMENT(S)	TESTED BY		
	APPROVED		

GROUP-S/N	POWER DISSIPATED	RIS. TEMP.	AMBIENT	GROUP-S/N	POWER DISSIPATED	RIS. TEMP	AMBIENT
49-1				-66			
S/N 77	1.06	128°F	85°F	S/N 68	0.927	115°F	79°F
	2.90	194	90		3.061	178	85
	4.65	255	95		5.176	235	90
	5.91	297	99		7.175	285	96
49-2					7.40	300	92
S/N 91	1.045	123	85	66-1			
	2.74	186	90	S/N 150	1.02	110	85
	4.44	249	95		3.04	183	102
	6.17	298	98		4.98	233	106
49-3					7.25	280	117
S/N 41	1.084	120	78		8.19	300	94
	2.803	186	88	-70			
	5.36	264	97	S/N 133-134	1.15	90	75
	6.10	296	102		2.93	115	80
49-4					5.04	135	85
S/N 17	0.770	96	73		7.06	170	90
	2.96	163	73		10.30	205	95
	4.85	216	79				
	6.10	256	88				
	7.18	283	90				
49-5							
S/N 113	0.956	108	72				
	3.046	184	76				
	5.275	258	82				
	6.01	289	90				

LABORATORY DATA SHEET Bendix SCINTILLA DIVISION, SIDNEY, N.Y.

Appendix

Table IV

TEST: 10 & 100MC OUTPUT DETECTION	SPEC.	PARA.	FCL	
TEST SPECIMEN: RADIO INTERFERENCE GUARD	DATE		TEMP.	RH.
TEST INSTRUMENT(S)	TESTED BY			
	APPROVED			

GROUP NO.	SERIAL NO.	R.F. INPUT POWER		10MC Eout (µV)		100MC Eout (µV)	
49-1	77	6 WATTS		●		*	
49-2	91			●		*	
49-3	43			26		*	
49-4	17			4300		30	
49-5	113			27		*	
66	58			●		*	
66-1				●		*	
	●	LESS THAN 1µV					
	*	NO DETECTABLE OUTPUT					

LABORATORY DATA SHEET Bendix SCINTILLA DIVISION, SIDNEY, N.Y.

Appendix

Table V

Test: R.F. POWER ATTENUATION

Spec.

Para.

Test Instrument(s)

L-19910-49-1 #1 END

Date

R Load =

FREQ	S/N #71	S/N #77	S/N #78	S/N #79			
KC/S	db	db	db	db			
.200	10.34	10.48	10.56	10.5			
.600		11.86	11.93				
.800		12.49	12.61				
1.0	13.27	13.11	13.27	12.87			
2.0		15.44	15.61				
3.0		16.58	16.66				
4.0		17.16	17.16	17.01			
5.0		17.41	17.49				
6.0		17.74	17.74				
7.0		17.82	17.94				
8.0		18.08	18.17				
9.0		18.25	18.35				
10.0	18.77	18.44	18.56	18.29			
15.0		19.43	19.51				
20.0		20.25	20.44				
25.0		21.35	21.38				
30.0		22.23	22.21				
40.0	23.78	23.85	23.90	23.08			
50.0		25.32	25.40				
60.0		26.86	26.95				
70.0		28.11	28.25				
80.0		29.39	29.60				
90.0		30.61	30.75				
100.0	30.01	31.52	31.98	30.68			
150.0		37.22	36.86				
200.0		42.29	42.65				
250.0		47.05	47.07				
300.0		51.40	51.35				
400.0		57.52	56.35	54.79			
500.0	80.71	62.70					
600.0		68.06					
700.0		74.51					
800.0		79.10					
900.0		83.22					
1000.0	85.2	88.06		86.15			

Table VI

Test R.F. Power Attenuation	Spec.	Para.
Test Instrument(s) L-19910-49-2 #1 IND		Date
		R Load =

FREQ. KC/SEC	S/N 91 DB	S/N 92 DB	S/N 94 DB	S/N 95 D.B.			
0.200	5.42	5.43	5.39	5.26			
0.600	5.57	5.57	5.53				
0.800	5.66	5.63	5.65				
1.0	5.82	5.79	5.79	5.77			
2.0	6.08	6.19	6.16				
3.0	6.40	6.52	6.44				
4.0	6.59	6.72	6.68	6.89			
5.0	6.83	6.92	6.85				
6.0	7.00	7.01	7.02				
7.0	7.10	7.14	7.14				
8.0	7.20	7.25	7.24				
9.0	7.31	7.36	7.36				
10.0	7.44	7.48	7.43	7.61			
15.0	7.85	7.82	7.84				
20.0	8.33	8.18	8.36				
25.0	8.88	8.74	8.91				
30.0	9.76	9.21	9.42				
40.0	10.87	10.34	10.63	10.13			
50.0	12.04	11.39	11.73				
60.0	13.15	12.43	12.77				
70.0	14.20	13.40	13.79				
80.0	15.21	14.28	14.79				
90.0	16.11	15.19	15.65				
100.0	18.20	18.36	16.46	15.61			
150.0	21.80	23.27	20.10				
200.0	25.08	27.00	24.53				
250.0	28.03	27.76	27.57				
300.0	31.22	29.82	30.35				
400.0	35.21	34.10	34.90	33.43			
500.0	39.35	38.10	38.85				
600.0	42.73	41.83	42.48				
700.0	46.39	45.26	46.23				
800.0	49.26	48.58	49.66				
900.0	51.06	51.19	52.14				
1000.0	52.46	53.36	54.15	53.02			

Test RF POWER ATTENUATION	Spec.	Para.
Test Instrument(s) ∠-19910-49-3 #1 END		Date
		R Load =

FREQ	S/N #[illegible]	S/N #41	S/N #42	S/N #43	S/N #45		
KC/S	db	db	db	db	db		
.200	7.34	7.35	5.05	6.3	7.30		
.600	7.51	7.47		6.38	7.47		
.800	7.56	7.53		6.42	7.49		
1.0	7.71	7.72	5.41	6.42	7.69		
2.0	8.32	8.14		6.45	8.24		
3.0	8.78	8.59		6.58	8.54		
4.0	9.08	8.83	6.87	6.77	8.90		
5.0	9.22	9.02		6.80	9.07		
6.0	9.45	9.18		6.78	9.18		
7.0	9.55	9.38		6.75	9.36		
8.0	9.66	9.36		6.82	9.50		
9.0	9.73	9.47		6.83	9.57		
10.0	9.88	9.74	8.23	7.16	9.71		
15.0	10.3	10.2		7.13	10.2		
20.0	10.8	10.4		7.33	10.5		
25.0	11.2	10.8		7.45	9.89		
30.0	11.6	11.1		7.65	11.4		
40.0	12.2	12.0	10.09	7.80	12.8		
50.0	13.0	12.7		8.59	12.8		
60.0	13.6	13.5		9.03	13.9		
70.0	14.3	14.2		9.37	14.8		
80.0	15.0	15.0		9.66	15.5		
90.0	15.6	15.8		10.05	16.0		
100.0	16.3	16.3	13.81	10.54	16.0		
150.0	22.2	20.2		11.66	21.2		
200.0	22.7	22.5		14.76	23.7		
250.0	25.0	25.1		[illegible]	24.6		
300.0	27.0	27.6		18.43	27.0		
400.0	30.5	31.2	24.99	21.75	30.8		
500.0	33.6	34.4		24.01	33.8		
600.0	36.6	37.5		26.96	37.1		
700.0	39.4	41.3		28.81	40.6		
800.0	41.1	42.6		30.65	42.9		
900.0	41.7	44.1		32.44	44.1		
1000.0	42.8	45.3	36.04	34.21	45.9		

Table VIII

Test RF Power Attenuation	Spec.	Para.
Test Instrument(s) L-19910-49-4 #1 END		Date
		R Load =

FREQ KC/S	S/N #17 db	S/N #18 db	S/N #19 db	S/N #24 db	S/N #25 db
.200	4.18	4.13	3.95	4.15	4.04
.600	4.23	4.22	4.04	4.25	4.13
.800	4.24	4.23	4.06	4.27	4.11
1.0	4.30	4.29	4.07	4.28	4.17
2.0	4.35	4.40	4.25	4.42	4.26
3.0	4.62	4.55	4.35	4.57	4.36
4.0	4.65	4.59	4.46	4.65	4.51
5.0	4.68	4.68	4.50	4.73	4.54
6.0	4.71	4.72	4.48	4.66	4.55
7.0	4.78	4.75	4.64	4.78	4.56
8.0	4.80	4.79	4.61	4.79	4.62
9.0	4.82	4.87	4.57	4.81	4.67
10.0	4.89	4.85	4.55	4.82	4.63
15.0	4.90	5.04	4.64	4.96	4.72
20.0	5.09	5.09	4.66	4.93	4.78
25.0	5.22	5.22	4.91	5.17	4.96
30.0	5.31	5.34	5.09	5.25	5.07
40.0	5.64	5.61	5.10	5.49	5.36
50.0	5.75	5.80	5.33	5.63	5.51
60.0	6.03	6.07	5.30	5.82	5.75
70.0	6.15	6.19	5.71	5.74	5.98
80.0	6.28	6.64	5.48	6.10	6.18
90.0	6.47	6.63	5.46	6.27	6.35
100.0	6.74	6.78	5.66	6.52	6.71
150.0	9.42	9.57	8.09	10.12	9.06
200.0	11.0	10.68	9.78	12.69	10.68
250.0	12.35	12.41	10.71	12.15	12.07
300.0	13.44	13.61	11.58	13.13	13.42
400.0	16.03	15.76	13.20	15.36	15.30
500.0	17.93	17.97	15.32	17.32	17.45
600.0	19.51	19.48	16.82	19.02	17.40
700.0	20.62	20.43	19.11	20.11	19.44
800.0	21.69	21.49	18.59	21.37	21.48
900.0	23.03	22.76	20.0	22.39	22.95
1000.0	24.00	23.81	20.78	23.21	23.41

Table IX

Test R.F. Power Attenuation	Spec.	Para.
Test Instrument(s) L-19910-49-5 #1 END		Date
		R Load =

FREQ. KC/SEC	S/N 113 DB	S/N 114 DB	S/N 115 DB	S/N 117 DB	S/N 118 DB		
0.200	6.29	7.06	6.27	6.26	5.98		
0.600	6.24		6.35	6.29	5.79		
0.800	6.28		6.35	6.28	5.98		
1.0	6.31	7.32	6.34	6.32	6.06		
2.0	6.45		6.57	6.46	6.14		
3.0	6.58		6.77	6.55	6.32		
4.0	6.66	7.73	6.90	6.64	6.41		
5.0	6.79		6.88	6.74	6.64		
6.0	6.87		7.06	6.82	6.83		
7.0	6.94		7.14	6.88	7.08		
8.0	7.00		7.16	6.90	7.22		
9.0	7.02		7.23	6.97	7.47		
10.0	7.03	8.34	7.25	7.04	7.61		
15.0	7.25		7.42	7.23	8.13		
20.0	7.38		7.59	7.43	8.34		
25.0	7.57		7.80	7.58	8.60		
30.0	7.81		8.12	7.79	8.69		
40.0	8.14	9.82	8.35	8.22	9.41		
50.0	8.55		8.80	8.61	9.86		
60.0	8.91		9.22	8.43	10.05		
70.0	9.38		9.49	9.34	10.24		
80.0	9.75		9.99	9.76	10.72		
90.0	10.27		10.34	10.15	11.06		
100.0	11.14	14.10	13.05	10.60	11.76		
150.0	14.90		15.36	12.60	13.48		
200.0	16.43		16.36	15.02	15.75		
250.0	18.72		18.54	17.20	18.0		
300.0	19.73		21.82	18.90	19.70		
400.0	22.09	26.57	22.18	21.88	22.78		
500.0	24.50		24.61	24.29	25.18		
600.0	26.93		26.82	26.49	27.80		
700.0	28.94		29.32	28.64	29.71		
800.0	31.06		31.31	30.53	33.09		
900.0	32.57		32.88	32.45	33.48		
1000.0	34.34	40.53	34.86	34.13	35.38		

Table 3

Test R.F. POWER ATTENUATION	Spec.	Para.
Test Instrument(s) L-19910-66 H 1 END		Date
		R Load =

FREQ. KC/SEC	S/N 52 DB	S/N 54 DB	S/N 56 DB	S/N 58 DB	S/N 62 DB		
.200	12.2	12.59	12.0	12.2	12.14		
.600	14.3		14.05	14.4			
.800	15.0		14.86	15.1			
1.0	15.5	16.50	15.43	15.6	15.88		
2.0	16.9		17.03	17.0			
3.0	17.8		17.60	17.8			
4.0	18.3		18.10	18.2			
5.0	18.9		18.60	18.7			
6.0	19.4		19.07	19.2			
7.0	20.1		19.49	19.6			
8.0	20.7		19.78	20.2			
9.0	21.3		20.37	20.7			
10.0	21.8	22.41	20.87	21.3	21.57		
15.0	24.7		23.52	23.9			
20.0	27.3		25.63	26.2			
25.0	29.6		27.69	28.4			
30.0	31.7		29.61	30.5			
40.0	35.5	34.63	33.78	33.9	34.28		
50.0	38.3		36.11	36.8			
60.0	41.2		38.92	39.6			
70.0	43.5		40.72	42.0			
80.0	45.6		42.95	44.1			
90.0	47.0		45.04	46.2			
100.0	48.7	47.65	47.84	48.1	48.42		
150.0	54.4		55.77	56.6			
200.0				61.3			
250.0				68.9			
300.0				74.2			
400.0				82.1			
500.0		84.39		88.3	101.22		
600.0				95.9			
700.0				93.6			
800.0				101.9			
900.0				104.6			
1000.0		103.49		107.1	108.77		

Appendix

Table XI

Test R.F. POWER ATTENUATION	Spec.	Para.
Test Instrument(s) L-19910-66-1 #1 END		Date
		R Load =

FREQ. KC/SEC	S/N 150 (DB)	S/N 151 (DB)	S/N 153 (DB)	S/N 154 (DB)	S/N 155 (DB)	S/N 157 (DB)	
0.200	9.39		9.35	9.32	9.16	9.10	
0.600							
0.800							
1.0	12.46		12.54	12.31	12.20	12.59	
2.0							
3.0							
4.0							
5.0							
6.0							
7.0							
8.0							
9.0							
10.0	18.91		18.75	18.27	18.67	19.32	
15.0							
20.0							
25.0							
30.0							
40.0	30.20		30.04	28.51	29.07	30.80	
50.0							
60.0							
70.0							
80.0							
90.0							
100.0	42.25		42.19	41.38	40.95	43.60	
150.0							
200.0							
250.0							
300.0							
400.0							
500.0	79.03		83.07	78.7	81.67	83.23	
600.0							
700.0							
800.0							
900.0							
1000.0	112.85		104.2	96.25	99.96	102.38	

Appendix

Table XII

Test: RF POWER ATTENUATION | Spec. | Para.

Test Instrument(s) | Date

1-19910-70 #1 END

R Load =

FREQ KC/S	121-122 SECTION A-1 db	121-122 SECTION B-2 db	124-125 SECTION A-1 db	124-125 SECTION B-2 db	127-128 SECTION A-1 db	127-128 SECTION B-2 db
.200	8.86	8.84	9.2	8.98	9.03	9.05
.600			9.47	9.27	9.27	9.41
.800			9.57	9.44	9.54	9.77
1.0	9.77	9.69	9.84	9.55	9.88	9.88
2.0			10.41	10.28	10.5	10.51
3.0			10.88	10.84	10.9	11.15
4.0			11.19	11.33	11.3	11.16
5.0			11.47	11.78	11.7	11.74
6.0			11.8	12.05	12.5	11.97
7.0			11.97	12.34	12.5	12.12
8.0			12.19	12.66	12.4	12.54
9.0			12.36	12.93	12.7	12.83
10.0	12.2	12.77	12.64	13.24	12.9	12.95
15.0			13.46	14.13	13.8	13.76
20.0			14.51	14.85	14.6	14.48
25.0			15.08	15.75	15.3	15.42
30.0			15.94	16.64	16.4	16.06
40.0	17.55	16.76	17.49	17.93	18.0	17.76
50.0			18.87	19.57	19.3	18.99
60.0			19.98	21.01	20.7	20.26
70.0			21.21	22.29	21.9	21.36
80.0			22.3	23.57	23.2	22.56
90.0			23.32	24.88	24.2	23.40
100.0	25.92	24.55	24.44	26.0	25.4	24.66
150.0			30.18	31.29	30.5	30.46
200.0			33.79	36.58		
250.0			37.64	41.01		
300.0			41.11	44.69		
400.0			47.52	51.51		
500.0	48.72	52.27	52.4	55.96		
600.0			57.76	62.86		
700.0			65.59	68.81		
800.0			67.27	72.85		
900.0			70.36	75.44		
1000.0	82.50	77.0	72.7	80.67		

Appendix

Table XIII

Test R.F. POWER ATTENUATION	Spec.	Para.
Test Instrument(s) L-19910-70 #1 END		Date
		R Load =

FREQ.	S/N 130-131		S/N 133-134	
KC/SEC	SECTION A-1	SECTION B-2	SECTION A-1	SECTION B-2
	DB	DB	DB	DB
.200	8.80	9.07	9.28	8.86
.600	9.28	9.32	9.43	9.29
.800	9.38	9.64	9.56	9.39
1.0	9.40	10.07	9.67	9.48
2.0	10.22	10.50	10.3	10.3
3.0	10.77	10.74	10.7	10.7
4.0	10.95	11.23	11.0	10.9
5.0	11.35	11.41	11.4	11.2
6.0	11.56	11.70	11.7	11.5
7.0	11.77	11.84	11.9	11.6
8.0	12.04	12.27	12.1	11.9
9.0	12.27	12.20	12.3	12.3
10.0	12.60	12.59	12.5	12.6
15.0	13.31	13.43	13.5	13.5
20.0	14.41	14.39	14.3	14.4
25.0	15.39	15.07	15.2	15.1
30.0	16.82	16.13	16.0	15.8
40.0	18.14	17.70	17.8	17.4
50.0	19.80	19.13	19.3	18.9
60.0	21.02	20.41	20.5	20.1
70.0	22.40	21.72	21.8	21.2
80.0	23.96	22.83	22.8	22.2
90.0	25.13	23.97	24.6	23.2
100.0	27.17	26.01	25.5	24.6
150.0	31.69	30.84	29.8	30.2
200.0	36.95	34.54	33.9	34.3
250.0	41.44	38.73	38.3	38.0
300.0	44.92	42.54	42.2	41.0
400.0	50.88	49.14	48.3	46.0
500.0	54.38	53.84	53.1	51.2
600.0	57.90	59.48	56.9	55.4
700.0	67.57	65.81	61.9	60.5
800.0	72.60	69.43	62.2	63.3
900.0	75.47	72.09		
1000.0	81.16	75.25		

A NOTE ON THE USE OF ATTENUATORS IN BALANCED AND UNBALANCED NETWORKS

by

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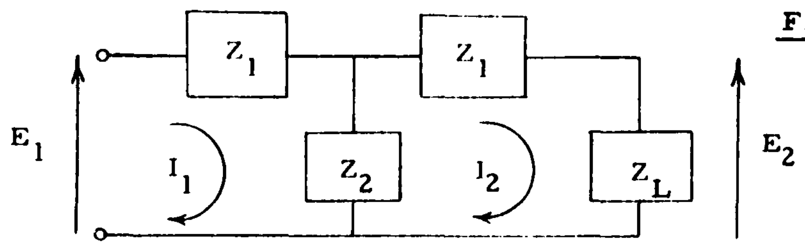
1. The purpose of this note is to analyze the problem of using a pair of "Radio-frequency Interference Guard" attenuators in a balanced two-wire circuit as compared with their performance in a co-axial circuit.

2. A well-known theorem of network analysis states: "Any passive 4 - terminal network may be completely represented, or replaced, at any frequency by a suitably chosen "T" or "Pi" network (or any network having at least three independent parameters) so far as external currents and voltages are concerned.

3. Unbalanced or Co-axial Network

The R.I.G. and its associated load EED may be represented as follows:

FIGURE 1



$$(1)\quad I_1 (Z_1 + Z_2) - I_2 Z_2 = E_1$$

$$(2)\quad I_2 (Z_1 + Z_2 + Z_L) - I_1 Z_2 = 0$$

$$\therefore I_2 = I_1 \left(\frac{Z_2}{Z_1 + Z_2 + Z_L} \right)$$

$$Z_{in} = \frac{E_1}{I_1} = \left[(Z_1 + Z_2) - \frac{Z_2{}^2}{Z_1 + Z_2 + Z_L} \right]$$

Hence, the attenuation for the unbalanced network may be stated as:

$$\alpha_u = 10 \lg \left| \frac{P_{in}}{P_{out}} = \frac{Re\,(E_1 I_1)}{Re\,(E_2 I_2)} = \frac{Re\,(I_1^2 Z_{in})}{Re\,(I_2^2 Z_L)} = Re \frac{Z_{in}}{\left(\frac{Z_2}{Z_1 + Z_2 + Z_L}\right)^2 Z_L} \right.$$

$$\alpha_u = \frac{(Z_1 + Z_2 + Z_L)\left[(Z_1 + Z_2)(Z_1 + Z_2 + Z_L) - Z_2^2\right]}{Z_2^2 Z_L}$$

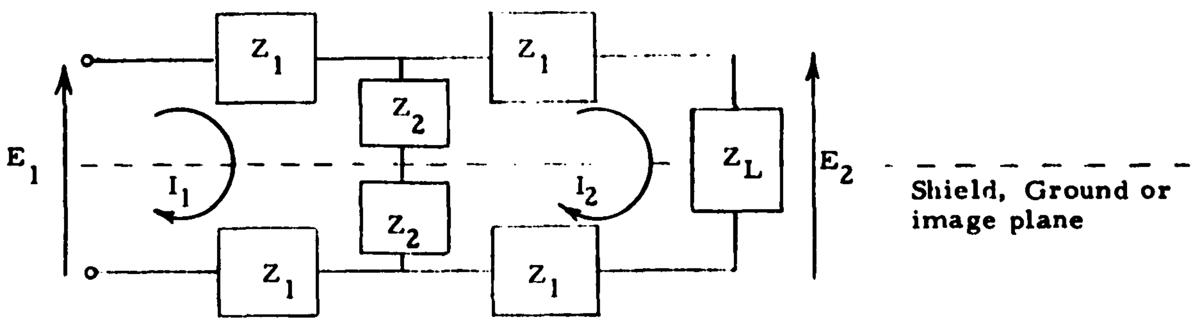
NB: Real parts of complex numbers will be understood to apply in this and all subsequent expressions for attenuation .

and we note that, if $Z_L \ll Z_1 + Z_2$ the attenuator approximates to a "constant current" source and $\alpha \simeq K/Z_L$ (e.g. if we halved the load resistance in a purely resistive load we would double the attenuation approx.)

4. Balanced Network

Two identical R.I.G.s and their associated load EED may be represented in a balanced two-wire circuit, as follows:

FIGURE 2



It is clear that, because the network currents are equal and opposite in the shield or ground plane, which is assumed to be of zero impedance, this dividing line between the two half circuits may be ignored and the network solved for I_1 and I_2 as shown above. It will be noted that the principle of "image circuits" has been abused by the use of a load Z_L instead of 2 Z_L.

$$(1) \quad I_1 (2Z_1 + 2Z_2) - I_2 (2Z_2) = E_1$$

$$(2) \quad I_2 (2Z_1 + 2Z_2 + Z_L) - I_1 (2Z_2) = 0$$

$$\therefore I_2 = I_1 \left(\frac{2Z_2}{2Z_1 + 2Z_2 + Z_L} \right)$$

$$Z_{in} = \frac{E_i}{I_1} = \left[(2Z_1 + 2Z_2) - \frac{4Z_2^{\,2}}{(2Z_1 + 2Z_2 + Z_L)} \right]$$

Hence, the attenuation of this balanced network may be stated as:

$$\alpha_B = 10 \lg \left| \frac{P_{in}}{P_{out}} = \frac{\mathrm{Re}\,(E_1 I_1)}{\mathrm{Re}\,(E_2 I_2)} = \frac{\mathrm{Re}\,(I_1^{\,2} Z_{in})}{\mathrm{Re}\,(I_2^{\,2} Z_L)} = \mathrm{Re} \frac{Z_{in}}{\left(\frac{2Z_2}{2Z_1 + 2Z_2 + Z_L}\right)^2 Z_L} \right.$$

$$= 2 \left\{ \frac{\left[(Z_1 + Z_2)(Z_1 + Z_2 + \cancel{Z_L/2}) - Z_2^{\,2} \right] (Z_1 + Z_2 + \cancel{Z_L/2})}{Z_2^{\,2} Z_L} \right\}$$

and we note that approximately : $\dfrac{\alpha_B}{\alpha_u} = 2$

But it is important to observe that, this factor of 2 is due <u>entirely</u> to the fact that we have failed to provide each half circuit with its original load impedance Z_L as in the unbalanced system. This is readily checked, by writing $Z_L = 2\,Z_L$ instead of Z_L in the expression for α_B when

$$\frac{\alpha_B}{\alpha_u} = 1$$

It is interesting to note that precisely the same effect is obtained in the unbalanced circuit if we halve the load resistance Z_L.

5. The input impedance ratio :

$$\frac{Z_{in\,(B)}}{Z_{in(u)}} = 2\,\frac{\left[(Z_1 + Z_2)(Z_1 + Z_2 + Z_L/2) - Z_2{}^2\right](Z_1 + Z_2 + Z_L)}{\left[(Z_1 + Z_2)(Z_1 + Z_2 + Z_L) - Z_2{}^2\right](Z_1 + Z_2 + Z_L/2)}$$

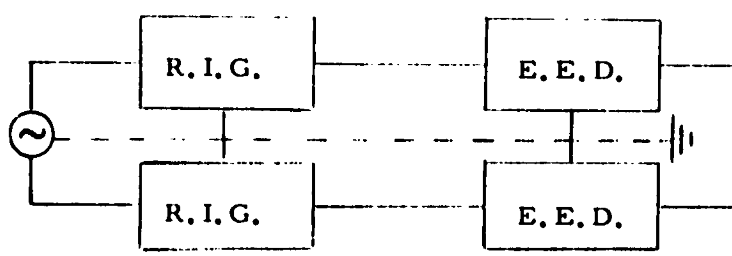
and if $Z_L \ll Z_1 + Z_2$ this ratio is approximately 2. Again we note that if the load impedance is doubled in the balanced system, this ratio is 2 exactly.

6. It is also clear that the power rating of the balanced system is twice that of the single circuit. The situation is analogous to that of resistors or lamps in series or parallel. It is immaterial whether they are connected in series or parallel - provided they carry their rated current and hence have their rated potential difference across their terminals, they will each dissipate the rated power.

7. Conclusions

If two identical co-axial networks containing the R.I.G. are placed side-by-side to form a balanced system as shown below each half circuit is entirely "unaware" of its neighbor.

FIGURE 3



This schematic diagram represents a double, shielded, co-axial system but it may equally well be contained in a common shield provided the e-m barrier of the R.I.G.s is brought out to the common shield. The system can then employ shielded, 2-wire (twisted) circuits. Under these conditions, and provided the load consists of 2 EEDs in series or of one EED of twice the impedance of the original then we have: -

a. Twice the power dissipation capacity

b. Twice the input impedance

c. The same attenuation as in the prototype unbalanced circuit.

8. However, if we use the same load EED in both the unbalanced and the balanced system then we have the attenuation and impedance ratios given in the previous analysis. The power dissipation capacity of the pair is still double that of a single unit.

(R. I. GRAY)
Wing Commander

10 November 1962

CODE 77820

REL		CH'D	DATE	APP'D

SPECIFICATION

TEST

L-19910-G7 CHANGE

SHEET 1 OF

ISSUED: 1/22/63

SCINTILLA DIVISION — THE Bendix CORPORATION — SIDNEY, N. Y., U. S. A.

QUALIFICATION TEST SPECIFICATION FOR RF ATTENUATOR-SINGLE UNIT FOR R & D PROGRAM

1. SCOPE

1.1. This specification is an adaptation of MIL-E-5272C (13 April 1959) to the specific requirements of an RF Attenuator.

1.2. This specification establishes the requirements and procedures for electrical and environmental tests for the RIG device. Procedures prescribed herein are to be utilized in subjecting the RIG device to simulated and accelerated electrical and environmental conditions.

2. APPLICABLE DOCUMENTS

2.1. The following documents form a part of this specification to the extent specified herein.

Specifications

Standards

Federal

Fed. Test Method
Std. No. 151 Metals; Test Methods

(Copies of documents required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. GENERAL INSTRUCTIONS

3.1. Test Facilities

3.1.1. General - The apparatus used in conducting tests shall be capable of producing and maintaining the test conditions required, with the equipment under test installed in the chamber and operating or non-operating as required. Changes in test chamber conditions may be the maximum permitted by the test chamber, but shall not exceed the applicable equipment specification requirements.

3.1.2. Volume - The volume of the test facilities shall be such that the bulk of the equipment under test shall not interfere with the generation and maintenance of test conditions.

3.1.3. Heat Source. - The heat source of the test facilities shall be so located that radiant heat shall not fall directly on the equipment under test, except where application of radiant heat is one of the test conditions.

3.1.4. Standard Conditions - Conditions for conducting the equipment operational test shall be as follows:

a. Temperature: 70°F + 30 -10
b. Relative Humidity: 90 per cent or less
c. Barometric Pressure: Local standard (Correct to 28 to 32 inches Hg if so specified in the applicable equipment specification.)

3.2. Measurements

All measurements shall be made with instruments the accuracy of which conforms to acceptable laboratory standards, and which are appropriate for measurement of environmental condition concerned. If tests are conducted at the contractor's plant, the accuracy of the instruments and test equipment shall be verified periodically by the contractor to the satisfaction of the procuring activity.

3.3. Test Sequence - Unless otherwise specified in the applicable equipment specification, it is recommended that the appropriate test sequence be selected from 5.1.

3.4. Performance Record - Prior to conducting any of the environmental test specified herein, the RIG device shall be given the following operational electrical tests.

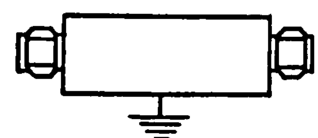


FIGURE 1

3.4.1. Using a General Radio Impedance Bridge No. 1650A, or equivalent, (Figure 1), check the resistance between the input (No. 1) pin and the housing. Repeat this check between the opposite end, the output (No. 2) pin and the housing. Check the resistance between the two pins. Record these three (3) resistances. The readings are to be recorded to three (3) places.

3.4.2. Using a General Radio Impedance Bridge No. 1650A, or equivalent, (Figure 1), check the inductance at 1,000 cycles, between the input (No. 1) pin and the housing. Repeat this check between the opposite end, the output (No. 2) pin, and the housing. Check the inductance between the two pins. Record these three inductances. The readings are to be recorded to three places.

3.4.3. Make the following measurements and computations with No. 1 end as the input and No. 2 end as the output.

3.4.3.1. Measuring ac voltage with .75 ohm termination at (No. 2) output end.

Connect the RIG as shown in Figure 2.

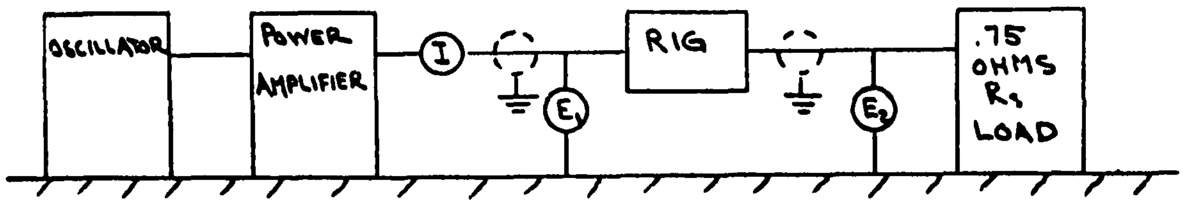


FIGURE 2

Oscillator	Hewlett Packard Model 200 C-D-20C-100KC. Measurement Corp. Model 65-B 100 KC-1MC.
Amplifier	General Radio Power Amplifier Type 1233A 20C-1MC
Ammeters	Weston Model 425 RF Meters (0-1.5) amp. - 2% accuracy.
Voltmeter	Fluke True RMS Voltmeter Type 910A 2% accuracy
R_s	.75 ± .02 Ohm resistive load - 1/2 watt - non inductive

Th. input current shall be m··.itored and held constant within 10% throughout the test.

3.4.3.2 Measuring Impedance with .75 Ohm Termination at (No 2) output end.

Connect the RIG as shown in figure below:

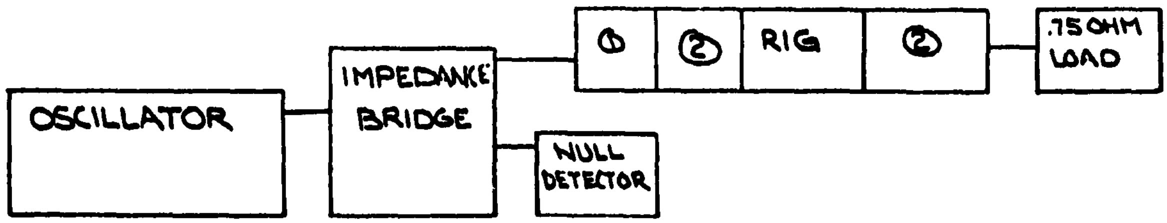


FIGURE 3

A. <u>Equipment for freq. up to 100 KC.</u>

Oscillator - Gen. Rad. 1210C-20C-100 KC or equivalent

Inductance Bridge - Gen. Rad. 1632A-20C-100 KC

Null Detector - Gen. Radio 1232A 20C-100 KC.

B. <u>Equipment for Freq. 100 KC to 1 MC.</u>

Generator - Gen. Rad. 1211C - 500 KC-50 MC or equivalent

Inductance Bridge - Gen. Rad 916 AL-50KC-5MC.

Detector - Stoddart N. M. -10 Receiver 100 KC - 150 KC or
Empire Noise and Field Intensity No-105

Item 1 - G. R. Type 874 to N
2 - Scintilla Adapter 21-31114

The input current shall be monitored and held constant within 10% throughout the test.

3.4.3.2.1 Take the following readings and perform the necessary computations

No. Points	1 ±5% Freq. KC	2 G_X	3 L_X	4 $\frac{1}{G_x}$ R_X	5 E_{in} E_1	6 E_{out} E_2
1	0.200					
2	0.600					
3	0.800					
4	1.0					
5	2.0					
6	3.0					
7	4.0					
8	5.0					
9	6.0					
10	7.0					
11	8.0					
12	9.0					
13	10.0					
14	15.0					
15	20.0					
16	25.0					
17	30.0					
18	40.0					
19	50.0					
20	60.0					
21	70.0					
22	80.0					
23	90.0					
24	100.0					
25	150.0					
26	200.					
27	250.					
28	300.					
29	400.					
30	500.					
31	600.					
32	700.					
33	800.					
34	900.					
35	1,000.					

Attenuation - db - 10 $\log_{10} \frac{P\ in}{P\ out}$ (Real Power)

$$db = 10 \log_{10} \frac{E_1^2 R_1 (R_2^2 + X_L^2)}{E_2^2 R_2 (R_1^2 + X_L^2)}$$

3.4.3.3. Plot dissipative attenuation versus frequency at each point on semi-log graph paper.

$$db = 10 \log_{10} \frac{E_1^2 R_1(R_2^2 + X_{2L}^2)}{E_2^2 R_2(R_1^2 (R + X_{1L}^2)}$$

3.4.3.4. Determine the dc attenuation with a .75 ohm termination at (No. 2) output end.

$$D.C.\ Attenuation = 10 \log_{10} \frac{E_1^2 \quad R_2}{E_2^2 \quad R_1}$$

3.4.4. Repeat all of 3.4.3. measurements, computations and graphs with No. 2 end as the input and No. 1 end as the output.

3.5. Criteria for Failure - Appreciable change in readings of 3.4.1. or 3.4.2. or 3.4.3. shall be evaluated for failure.

4. ENVIRONMENTAL TEST PROCEDURES AND REQUIREMENTS

4.1. High Temperature Tests

The surface of the RIG device shall be raised to 160 F +0 -10 F for 4 hours. At the conclusion of this period and while still at the test temperature, the equipment shall be operated in accordance with 3.4.1. and 3.4.2. The RIG device shall then be returned to standard conditions and again operated and inspected visually as specified in 3.4.1. and 3.4.2.

4.2. Low Temperature Tests

The RIG device shall be soaked for one hour in a test chamber maintained at a temperature of -65 F. While at this temperature, the RIG device shall be operated in accordance with 3.4.1. and 3.4.2. The RIG device shall then be returned to standard conditions and again operated and inspected visually as specified in 3.4.1. and 3.4.2.

4.3. Temperature Shock Test

The RIG device to be tested shall first be placed within a test chamber wherein a temperature of 85 C (185 F) is maintained. The RIG device shall be exposed to this temperature for a period of one hour, at the conclusion of which, and within five minutes, the RIG device shall be transferred to a chamber having an internal temperature of -67 F. The RIG device shall be exposed to this temperature for a period of one hour. This constitutes 1 cycle. The number of complete cycles shall be four. The duration of exposure at each extreme temperature shall not be less than that specified and may be extended to overnight exposure to prevent interruption of the transfer sequence. At the conclusion of the fourth cycle, the device shall be removed from the test chamber, returned to standard temperature and inspected as directed in 3.4.1. and 3.4.2.

4.4. Humidity Tests

With the ends sealed with suitable sealed plug or equivalent, the RIG device shall be placed in the test chamber and simulate installed conditions; the temperature and relative humidity in the chamber shall be + 49 C (+120 F) and 95 percent, respectively. The test conditions shall be maintained for 360 hours. At the conclusion of this period, the device shall be returned to standard conditions. Moisture may be removed by turning the device upside down or wiping. Drying by air blast will be permitted. The device shall then be operated and inspected within one hour as directed in 3.4.1. and 3.4.2.

4.5. Salt Spray Tests

RIG devices with the connector ends sealed by means of applicable mating plugs, shall be subjected to salt spray per MIL-STD-202, Method 101, Test Condition B. Following exposure, salt deposits shall be removed by a gentle wash in running water, not warmer than 100 F and a light brushing. The samples shall be visually examined for corrosion detrimental to its intended mechanical function.

4.6. Vibration

This procedure applies to equipment which mounts within 245° cone around the exhaust area of a turbo-jet aircraft engine or on the structure of missiles propelled or launched by high-thrust rocket engines. Although the tests are

of comparatively short duration, they are based upon the most severe conditions likely to be encountered in missiles, and should be adequate for most applications, provided that, where possible, consideration is given to location so as to avoid extreme environmental conditions. The specimen shall be attached, by clamping about its diameter, to a rigid fixture capable of transmitting the vibration conditions specified herein. The amplitude of applied vibration shall be monitored on the test fixture near the specimen mounting points. Operating requirements and tolerances shall be as specified below.

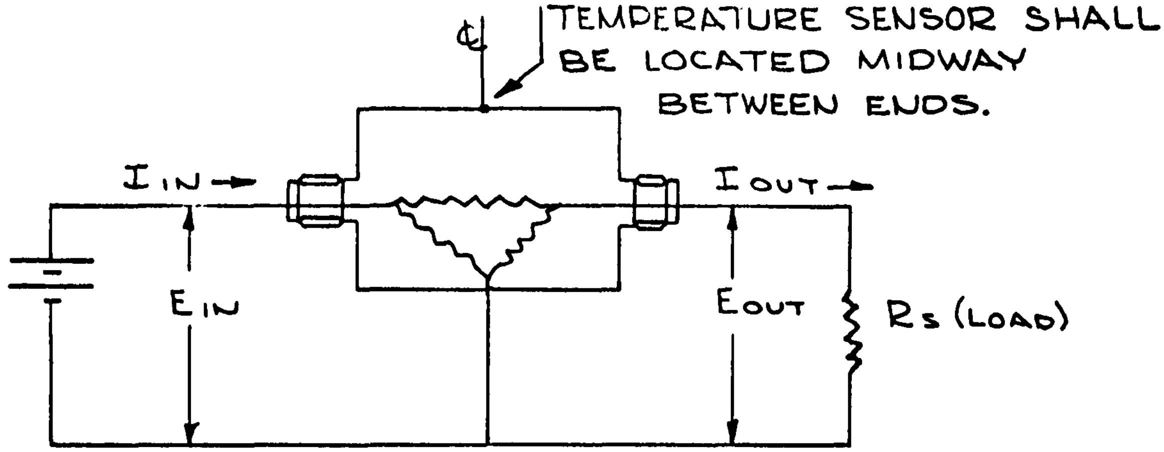
4.6.1. Cycling - The specimen shall be subjected to cycling vibration according to the amplitudes and accelerations outlined below. The rate of change of frequency shall be logarithmic and such that one hour is required to proceed from 20 to 2,000 back to 20 cps. When there is no provision for logarithmic cycling, other automatic cycling rates of frequency change may be used. The cycling test period for each of the 3 mutually perpendicular axes shall be two hours, making total test time of six hours.

Frequency (CPS)	Sinusoidal Vibration Levels
20 - 87	0.050 in. D. A.
87 - 2000	± 20 g

4.7. Shock Test

A shock testing machine designed and fabricated according to JAN-S-44, or equivalent, shall be used to produce the impacts required. The device shall be mounted as in the vibration test, 4.6.

Three resilient impacts shall be applied, in turn, in each direction along each of the three orthogonal axes of the specimen, by dropping the carriage from a suitable drop height to provide a 50 g peak acceleration. At the conclusion of this test, the device shall be inspected as directed in 3.4.1. and 3.4.2.



Power Dissipated by Device = $E_{in} I_{in} - E_{out} I_{out}$

FIGURE 6

4.8. D.C. Temperature Rise

With the RIG device assembled as described in Figure 6, the surface temperature of the RIG device shall be recorded for the values below. The device should be tested in such a manner as to preclude any heat sinks or convection currents other than of a negligible nature. The ambient temperature shall be 70 +30 -10 F.

Power Dissipated by RIG Watts	Maximum Measured Surface Temperature
1.0	*
3.0	
5.0	
7.0	
9.0	To maximum wattage
11.0	To maximum wattage

*Do not exceed 300 F.

4.9. Terminal Pull Test

A force of 50 pounds shall be applied between the terminals where the connections are made. The force is to be applied gradually and held for 30 seconds. No relative movement shall be visually observed between the parts, nor shall there be any signs of the coupling nut becoming disengaged from its part.

At the conclusion of this test the device shall be inspected as directed in 3.4.1. and 3.4.2.

Figure 7

Equipment for Figure 7.

Transmitter; 1. 10 megocycle crystal controlled Millen Model 90,800 -50 watt
2. 50 megocycle crystal controlled SCR 522 - 15 watt output
3. 100 megocycle crystal controlled SCR 522 - 15 watt output

Detectors: 1. M. C. Jones Model 263 Micromatch .5-225 mc. to establish impedance match.
2. Empire model NF 105 Radio Interference Noisemeter used to detect output level 1 MV sensitivity.
3. Leads and Northrop Model 8657-C Potentiometer.

4.10. A. C. Temperature Rise

4.10.1. Conditions of Test (A. C.)

Continuous power shall be applied for 1 hour with the RIG device in the circut as shown in Figure 7. Power shall be applied until the temperature sensor reads a surface temperature of 300° F midway between the ends. The ambient temperature shall be 70°F +30° -10°F. The device shall be tested in such a manner as to preclude any heat sinks or convection currents other then of a negligible nature.

4.10.2. Frequency and output detection:

D.C., 10 mc, 50 mc and 100 mc continuous power shall be applied to the RIG device. A suitable detector as shown in figure 7 shall be used to determine if any measurable output power can be detected.

5. SEQUENCE

5.1. Testing Sequence - All Units

		Required Paragraph
1.	High Temperature	4.1
2.	Low Temperature	4.2
3.	Thermal Shock	4.3
4.	Vibration	4.6
5.	Shock	4.7
6.	Humidity	4.4
7.	D.C. Temperature Rise	4.8
8.	A.C. Temperature Rise	4.10
9.	Terminal Pull	4.9
10.	Salt Spray	4.5

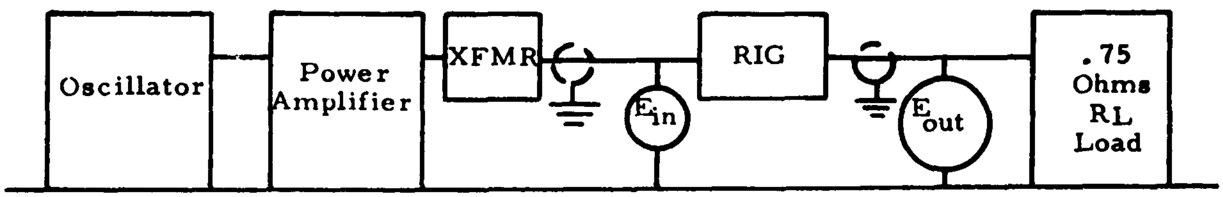
Addendum

to

Specification L-19910-67

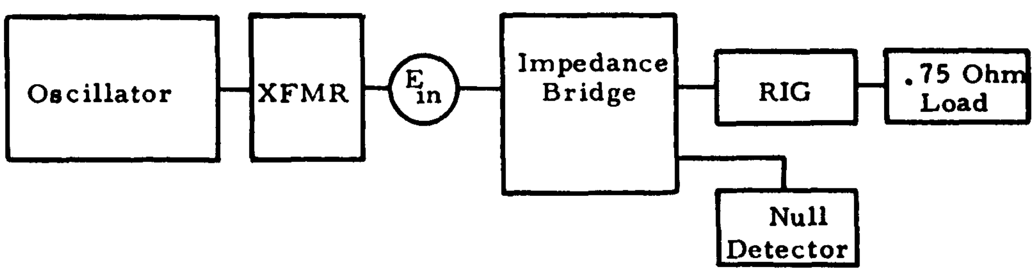
In order to obtain the test data using the test procedures outlined in the main body of this report, it was necessary to make certain equipment and test diagram changes in specification L-19910-67. These changes do not alter the scope of the test program but do reflect the use of additional equipment. The changes were as follows:

Paragraph 3.4.3.1 - Figure 2 and the equipment used were as indicated below:



Oscillator	Hewlett Packard Model 650A, or equivalent
Amplifier	General Radio Power Amplifier Type 1233A, or equivalent.
Voltmeters	Fluke True RMS Voltmeter Type 910A, or equivalent Empire Field Intensity Meter NF-105, or equivalent
Transformer	General Radio 1632-P1, or equivalent
R_L	.75 $\pm$ .02 Ohm Resistive Load-1/2 Watt Non-inductive

Paragraph 3.4.3.2 - Figure 3 and the equipment used were as follows:



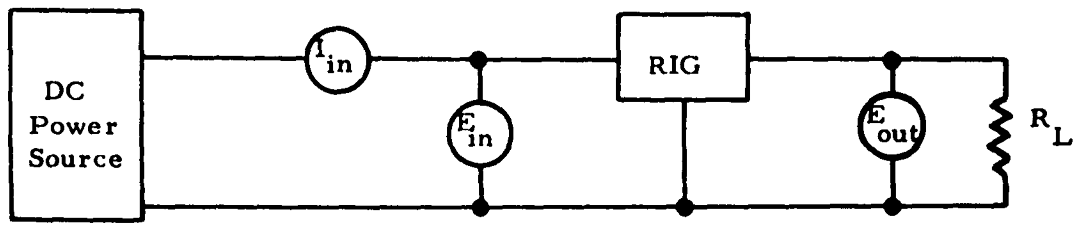
A. Equipment for frequencies up to 100 KC

Oscillator	-	Hewlett-Packard Model 200 CD, or equivalent
Impedance Bridge	-	General Radio Type 1632A, or equivalent
Null Detector	-	General Radio Type 1232A, or equivalent Stoddart Field Intensity Meter Model NM-10A, or equivalent
Voltmeter	-	Ballantine AC Voltmeter Model 643, or equivalent
Transformer	-	General Radio Type 1632-P1, or equivalent
Load	-	.75 $\pm$ .02 ohm resistive load, 1/2 watt, non-inductive

b. Equipment for frequencies 200 KC to 1 MC

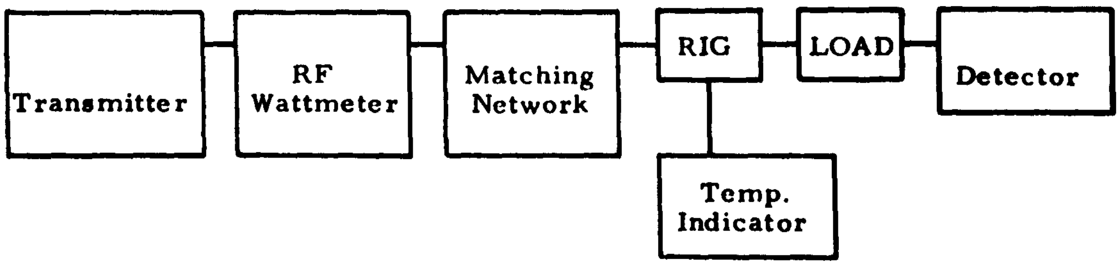
Oscillator	-	Measurement Signal Generator Model 65B, or equivalent
Impedance Bridge	-	General Radio Type 916AL, or equivalent
Null Detector	-	Empire Field Intensity Meter Model NF-105, or equivalent

DC attenuation was measured using the following diagram and test equipment.



I_{in} - Kiethley Electrometer model 610A
E_{in} and E_{out} Fluke Differential DC Voltmeter model 801

Paragraph 4.10.2 - Figure 7 and the equipment used for the 10 and 100 MC RF test were as follows:



100MC	Transmitter	- SCR 522
10MC	Transmitter	- Millen Model 90, 800 or equivalent
	RF Wattmeter	- M.C. Jones Model 263 or equivalent
	Detector	- Empire Field Intensity Meter NF-105 or equivalent
	Temperature Indicator	- Brown Model 153 x 62P8-X-26 or equivalent
	Load	- 0.75±.02 Ohm resistive load - 1/2 watt - non-inductive

Report Responsibilities

The development activities reported herein have been the responsibilities of the following persons in the areas indicated.

General -	R. R. Mero, Design Engineer, Senior
Analytical -	F. E. Hanni, Project Engineer, Research
Testing - Research -	D. E. Clark, Project Engineer, Senior
Testing - Environmental -	M. A. Champlin, Project Engineer, Senior

Bibliography

T.M. No. W-7/62 Series and Parallel Arrangements of Electrically Initiated Explosives by Wing Commander R.I. Gray

"A Note on the Use of Attenuators in Balanced and Unbalanced Networks" by Wing Commander R. I. Gray (10 November 1962)

Memo on Attenuation of RIG at DC by Lyde S. Pruett of NWL, dated November 13, 1962.

Requirements of the Radio-Frequency Interference Guard (RIG) by J.W.L. Lewis